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Appendix A - Pre-Experiment Forms

A.1. Consent Form

Informed Consent for Participants of Investigative Projects

Title of Project: Empirical Investigation of Sociotechnical Issues in Engineering Design

Research Investigator: Joe W. Meredith

I. Purpose of this Research

You are invited to participate in a study about engineering design. This research will consider various approaches to the design process to determine the superiority of one approach over the others. About 180 participants will be involved in this research.

II. Procedures

Participants will be assigned to teams. Teams will be given a set of requirements for the design of a system. Subject teams will design the system, build the system using LEGO toys, and their performance determined. The experiment is expected to take from two to three hours. Some teams will be able to use computers in the performance of the design.

III. Risks

There are no risks associated with this research.

IV. Benefits of this Research

This research will provide insight in the proper design of future engineering processes for design to engineering students. No promise or guarantee of benefits has been made to encourage you to participate.

V. Extent of Anonymity and Confidentiality

The results of this study will be kept strictly confidential. Individual performance will not be assessed as this is a team experiment. All results will be summarized at the team level. Individuals participating will not be identified except to the research team.

Video and audio taping of the experiment may occur. The tapes will be maintained by the investigator. No one else will have access to the tapes. After transcription of data from the tapes, they will be destroyed no later than one year after creation of the tape.

VI. Compensation

No monetary compensation will be provided for participation in this experiment. However, a cash award bonus will be given to the team that achieves the highest performance level of the experiment.

VII. Freedom to Withdraw

You are free to withdraw from this study at any time without penalty.

VIII. Approval of Research

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University and by the Department of Industrial Engineering.

IX. Subject's Responsibilities

I voluntarily agree to participate in this study. I agree to abide by all of the rules of the experiment. I also agree to not discuss any aspect of the research with others, except my teammates, after the conclusion of the research.

X. Subject's Permission

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.

______________________________________ ____________________

Signature Date

Should I have any questions about this research or its conduct, I will contact:

Joe W. Meredith Research Investigator	540-231-3600	jmeredit@vt.edu
Dr. Brian M. Kleiner Faculty Advisor	540-231-4926	bkleiner@vt.edu
Dr. Tom Hurd Chair, Institutional Review Board	540-231-5281	

A.2. Demographic Form

DEMOGRAPHIC FORM

Name: ________________________________ Team Name**:** _______ Function: _____________

Age: _____ Sex: ____ Major: __________________________________ GPA: _______

Home Phone: _________ Office Phone: _____________ Email Address: ___________________

Years of experience in engineering or building construction work setting: ________

Please Mark the Following:

YES	NO	
		I have used AutoCAD previously.
		I am familiar with the concept of life-cycle cost.

Please write down my name and how to contact me so you can call me if there is a problem:

Joe Meredith

231-3600 Work 961-5919 Home

jmeredit@vt.edu

Appendix B - Team Formation and Assignment to Treatments

B.1. Team Formation

Participants will be randomly assigned to teams. This process assumes that teams will be formed from participants in a given section of an engineering or building construction course. Participants must be randomly assigned to teams to preclude the best students from teaming together.

A constraint of the random selection process is that at least one member of each team must be familiar with AutoCAD. Therefore, class members with AutoCAD expertise will be identified first. These members will be assigned a team. The remainder of the class will then be assigned to three and six person teams using a random number generator.

B.2. Team Assignment to Treatments

There are four treatments to which large and small teams must be randomly assigned:

- Sequential Using the Computer (SC)
- Sequential Not Using the Computer (SN)
- Concurrent Using the Computer (CC)
- Concurrent Not Using the Computer (CN)

Teams will be assigned to treatments by using a random number generator. Teams will not know what treatment they have been assigned to.

B.3. Team Numbering

Teams will be assigned numbers that provide information about the treatment that the team was assigned to and the sequence of their trial in the treatment and the sequence of their trial in the entire experiment.

Teams will be numbered by the researcher using the following convention:

First Character	x	Sequential letter of the alphabet from A to AN	
Second Character	-	Dash	
Third Character:	S	Sequential Engineering	
	C	Concurrent Engineering	
Fourth Character:	C	With Groupware	
	N	Without Groupware	
Fifth Character:	L	Large Teams	
	S	Small Teams	
Sixth Character:	-	Dash	
Seventh Character:	i	Sequence Number of condition	(i=1,5)
Eighth Character:	-	Dash	
Ninth/Tenth Character:	j	Sequence of Experiments	(j=1,40)

Appendix C - Experimental Instructions

C.1. General Instructions

C.1.1 Pre-Experiment Instructions When Forming Teams

(The following text in italics are instructions and notes to the researcher. The text not in italics are statements that the researcher will make in the conduct of the experiment).

The researcher will introduce himself to the class.

My name is Joe Meredith. I am a doctoral student in Industrial and Systems Engineering. I am conducting research on the engineering design process. Your professor has agreed to let me solicit you as participants in an experiment. My expectation is that the experiment will be fun and show you what engineering design is all about.

Distribute the Consent Form (Appendix A.1) and Demographic Form (Appendix A.2).

Please read and complete the Consent Form and Demographic Form then I can assign you to teams.

Determine the number of students that are competent in AutoCAD. This will determine the number of teams that can be created.
Assign students to teams in accordance with the procedure in Appendix B.
Determine when the experiment will be conducted with each team.

The last thing that we'll do today is pick a mutually acceptable time to conduct the experiment. The experiment should take about 3 hours so it would probably be best to schedule it at night. Please decide among your team which night suits best. If you can't find an acceptable night, then select a time on the weekend. If you can't do it then, then select a time during the week When you've reached consensus, let me know and we'll schedule it. Once you have a scheduled time, please write it on your demographic form and give them to me.

All experiments will be held in the Macroergonomics and Group Decision Systems Laboratory in Whittemore Hall on the fifth floor. Once I have all the demographic forms from your team you're free to leave and I'll see you at the experiment. If you can't make the scheduled time, please call me. I will confirm the time of the experiment by email.

Contact each participant prior to the experiment by email and phone to confirm their attendance.

C.1.2 Experiment

Distribute the Consent Form (Appendix A.1) and Demographic Form (Appendix A.2) if not previously completed.

The first step in the process is to ask you to sign a Consent Form and Demographic Form, if you haven't already done so, to participate in the experiment. At this time I will distribute the Consent Form and Demographic Form. I ask that you read it and sign it.

Pause while Consent Form and Demographic From are completed, if necessary.
Start videotape.

Let me emphasize the part about not discussing the experiment with anyone other than your teammates. You might be giving some valuable information to a competing team. Do you have any questions thus far?

Assign participants to functions (i.e., design, manufacturing , support).

The person who is the most knowledgeable about AutoCAD should be your designer. The rest of the team have been randomly assigned to the other functions of manufacturing and support. Please wear your functional name tags in a conspicuous place.

The person who is the designer will be responsible for the CAD drawing of the system. The person who has drawn manufacturer will be responsible for assembling the system. The person who is designated as the support person will be responsible for calculating life-cycle cost. There will be a training exercise on AutoCAD, assembly of LEGOS, and the calculation of life-cycle cost.

At this time I would like to give you a copy of the Mission Possible Case.

Distribute System Performance Requirements Statement (Appendix D.1.1).

Please read the description of the case.

Pause while the case is being read.
Walk to the experimental setup.

So, let's review the problem. Your team is going to design a system to move the ping-pong ball from the starting point to the finish line by going over or around the hurdle. Please don't try to go through or under the hurdle!

The ball can roll over or fly over the finish line. But, it must cross the line - not the extended line.

You may not use the wall as part of your system. If your solution requires a wall, then build a wall out of LEGOs or other materials but you can not use the room wall.

You may not lift the ball from its starting location and put it on your system. The ball will be sitting on that LEGO piece at the commencement of testing.

You can hold your stem in tension or some other form of potential energy. Or, if you use the motor, you can turn the motor on. But you cannot interact with your system during testing.

Are there any questions so far?

Respond to any questions that are asked.
Distribute Time Card and Exercise Log (Appendix D.1.2).

The support person is responsible for keeping track of time on the Time Card and Exercise Log. Please note that task time is kept in minutes but the exercise times are in minutes and seconds.

Conduct LEGO Tutorial (Appendix D.1.3).

Please read this tutorial on LEGOS.

The researcher will now follow the specific instructions for the particular treatment that the team will be performing.

C.2. Specific Instructions

C.2.1. Sequential Engineering With (SC) and Without Computer Support (SN)

C.2.1.1. Conceptual Design

Please log the start time of conceptual design on your time card. The purpose of conceptual design is simply to reach agreement on a feasible approach. You should try to work as quickly as possible since you will only have a maximum of 60 minutes for this task.

The following only applies to conditions with computer support.

In this experiment we are going to use a special kind of software called groupware to help you arrive at agreement. The software is quite easy to use. I will explain it as we go along.

When you have reached agreement on an approach and are ready to proceed to the next task, detail design, please let me know.

Distribute the goals of the design organization (Appendix D.1.4.1) to their members.

At this time, I'd like to distribute the functional goals of the design organization. You are being individually evaluated on your ability to achieve the goals of your functional organization. Remember to let me know when you've reached agreement.

Lead the Groupware process. Prior to beginning the session, ensure that the ideas and voting from a previous session have been cleared. Log the moderator and participant stations on by clicking on the GroupSystems Icon. Enter each login name and password. Click on "Folders" on the moderator station. Prior to the participants arrival, an agenda has been created with two tasks: a Categorizer activity and a Vote activity. Open the folder called "Joe's Experiment" and select the Categorizer activity at the leader station. Make sure that the *previous lists at each participant station have no entries and that Group Settings have been set to allow participants to View Results. From the Agenda menu choose Join Activity by clicking on the Running Man icon. From the Group menu, choose Start Participants by clicking on the Pointing Hand icon. Select the participants to be started then close the dialog box by choosing OK. Confirm that all participants have an idea generation screen. Click on the Categorizer menu choice, then Open Private List. State the following to the group:*

While using the groupware tool you may not talk among yourselves. On your workstations, please click on Categorizer, and then Open Private List. You can now type in your ideas for moving the ball across the hurdle. Click on Add, type in an idea, and then click on the save button to make a list of as many ideas as you wish. After you are through entering ideas, click on Close and let me know. You will have a maximum of 10 minutes to create ideas.

After all participants have ended creating ideas, collect the ideas to the public list.

At this time I would like you to mark all of the items that you would like to submit to the group by clicking on the item while holding the shift key down. Then click on Submit.

The researcher collects the ideas by clicking on Categorizer and Collect Ideas.

After the items have been collected, then click on Close. Other's ideas that you have not read will show up on your screen with a red exclamation mark.

You can enter comments about others ideas by selecting the item on which you want to comment by clicking on the Eyeglasses icon. You many then add comments about the idea. After you have entered a comment, please click on the submit button and your comments will be sent to your team members for their review. The number before the slash will show the number of comments that have been submitted. The number after the slash will be red if you have not read a comment.

After you have exhausted all of your comments on other's ideas please let me know. We will then vote and rank order the ideas.

When everyone has signaled that they are done, from the leader's Group menu, choose Stop Participants by clicking on the Hand icon. Select the participants that you want to stop, then choose OK to close the dialog box.

From the leader's Group menu, choose Shift Activity by clicking on the Arrows icon. From the Shift Data To option area, select Existing Agenda Activity and choose OK to close the dialog box. From the Vote menu, choose Select Voting Method by clicking on the Scale icon. Select Rank Order, then choose OK to close the dialog box. Choose Yes to switch to voting mode. Start participants by clicking on the Pointing Hand icon. Select participants, then click on OK.

At this time you will select the item that you want to move by clicking and dragging it to the desired position in the list. Continue until the list is in the order that you prefer. From the vote menu, choose Cast Ballot. Then confirm that you are casting your ballot by clicking on Yes. Please let me know when you are complete.

After all ballots are cast, Start Participants and select View Results from the Vote menu so they can see the voting results on their screen by clicking on the Bar Chart icon.

Please click on View Results from the Vote menu. You may choose the idea that got the most votes or you may now discuss among yourselves which idea you would like to select as the concept for your design.

Print a report showing the results of the voting task by clicking on Close at the bottom of the moderator's screen, then File, and Reports. Click on the Plus sign and add Agenda, System Concept, Vote, and People. Print a copy of the list of ideas with comments before exiting GroupSystems. When finished with GroupSystems close the voting activity. Click on File and Exit confirming that you wish to exit GroupSystems. Be sure to terminate and log-out all participants stations. When the group says that it has reached agreement, distribute the goals of the manufacturing organization (Appendix D.1.4.2) to the manufacturing team member(s).

Remember that you are being individually evaluated on your ability to achieve the goals of your functional organization. At this time, you can reconsider your design concept in light of the goals of the manufacturing organization. Let me know when you've reached agreement.

When the group says that it has reached agreement, distribute the goals of the support organization (Appendix D.1.4.3).

Remember that you are being individually evaluated on your ability to achieve the goals of your functional organization. At this time, you can reconsider your design in light of the goals of the support organization. Please let me know when you've reached agreement and are ready to proceed to detail design.

The following applies to conditions without computer support.

We will use the nominal group technique to reach agreement. Let's do a brief tutorial on the nominal group technique or NGT. There are five steps in a NGT process. The first step is for each person to silently write down their ideas. The next step is to write down everyone's ideas on the wall in a round-robin manner with no discussion of each idea. The third step is to combine and clarify ideas. The fourth stage of NGT provides an opportunity for individual voting on the ideas. The fifth step is that after we've voted we'll discuss the results and make sure that everybody supports the result. I think that you will see that NGT is quite easy to do, even if you haven't done it before.

Distribute the goals of the design organization (Appendix D.1.4.1).

At this time, I'd like to distribute the functional goals of the design organization. You are being individually evaluated on your ability to achieve the goals of your functional organization.

Lead the NGT process.

Let's begin the nominal group technique process. Without talking, individually write down on your notepad a list of concepts for systems that could achieve the system requirements. When you're done, please let me know and we'll go on to step 2.

When the group says that it is complete or a maximum of 10 minutes passes, begin step 2.

I would now like to record your ideas on the whiteboard taking one idea from each of you at a time until all of the ideas are posted. We will not challenge any of these ideas and we will eliminate duplicates.

Record all ideas, then begin step 3.

Now that all of the ideas are posted, let's discuss them. All of you must agree to any changes that we make to a concept.

Once the list has been completed, begin step 4 voting.

Now that we have the final list, let's vote on which idea has the most support among the group. I'd like you to write down your top five ideas and give 5 points to the best idea, in your opinion, and 4 points to the next best, and so on. After you're done, we'll write the points up here on the board.

Record the votes and note the group's highest ranking decision. Begin step 5.

The final step is for the group to decide whether the decision that you arrived at using the NGT process is the one that you want to use. Please discuss among yourselves if you want to use this decision or pick another one from the list. Please let me know when you've reached agreement and are ready to proceed to detail design.

When the group says that it has reached agreement, distribute the goals of the manufacturing organization (Appendix D.1.4.2) to the manufacturing team member(s).

Remember that you are being individually evaluated on your ability to achieve the goals of your functional organization. At this time, you can reconsider your design concept in light of the goals of the manufacturing organization. If you would like to vote again based on this new information you can or you can just discuss among yourselves whether this information changes your selection.

When the group says that it has reached agreement, distribute the goals of the support organization (Appendix D.1.4.3).

Remember that you are being individually evaluated on your ability to achieve the goals of your functional organization. At this time, you can reconsider your concept design in light of the goals of the support organization. Again, if you would like to vote again based on this new information you can or you can just discuss among yourselves whether this information changes your selection. Please let me know when you've reached agreement and are ready to proceed to detail design.

The following applies to all sequential conditions.

When the group says that it is ready to proceed to detail design, have them complete the Design Concept Form (Appendix D.1.5), the System Concept Diagram (Appendix D.1.6), and the Preliminary Design Review Form (Appendix D.1.7).

Please select one person to complete the Design Concept Form. Select one person to draw a top-level sketch of the system on the System Diagram Form.

Conceptual design is now complete, please write the stop time on the time card. Then, please complete the Preliminary Design Review Form individually.

The researcher completes all fields on the Researcher's Log. Restart Participant 3 so they can access the life-cycle cost template.

C.2.1.2. Exercises

At this time we will conduct three exercises to make sure that the design people know how to use AutoCAD, the manufacturing people know how to put LEGOs together and read a three-view drawing, and the support people know how to use the EXCEL life-cycle cost spreadsheet.

These exercises are not part of the experiment so if you encounter any problems, please let me know as soon as possible so we can get them resolved.

See Section C.3.1 for a description of the learning objectives of the exercises. Conduct AutoCAD tutorial (Appendix D.2.1.) by distributing tutorial instructions.

Please complete this tutorial on AutoCAD.

Time the tutorial. Review the drawing to make sure that it is correct. Repeat the exercise until the drawing is accurate. Conduct the LEGO Assembly Tutorial (Appendix D.2.2) by distributing tutorial instructions.

While your designer is working with AutoCAD I would like to conduct another experiment to measure how long it takes you to assemble a system given the parts and a three-view drawing. Here is a bag of parts that can be assembled into the car shown in your drawing. I will time how long that it takes you to put it together correctly.

Time the assembly experiment. Conduct the life-cycle cost tutorial (Appendix D.2.3) by distributing tutorial instructions.

While the other exercises are in process, I would like to conduct an exercise in the calculation of life-cycle cost.

Time the LCC tutorial. When all tutorials are satisfactorily complete conduct detail design.

C.2.1.3. Detail Design

We are now ready to begin the detail design task. Please write the start time of detail design on your time card.

The purpose of this task is to convert your idea to a design that can be built using LEGOS. A measure of your team's performance is how accurate and complete your instructions are. If the manufacturer makes mistakes, it will count against your team's performance, so be as clear as you can be.

You may provide your instructions in the form of drawings, sketches, and/or text descriptions. Your instructions can also be in the form of dimensions and/or identification of individual pieces.

You must use the AutoCAD computer-aided design package to create a one-view drawing of the subsystem that interacts initially with the ball.

Distribute the goals of the design organization (Appendix D.3.1.1).

At this time I will distribute the goals of the design organization. Remember that you are being individually evaluated on your ability to achieve the goals of your functional organization. During this task you may not build the entire system but you can build components, subsystems, or prototypes to check out your approach. This task will be complete when you finish a one-view CAD drawing, and supporting sketches of other views of your system. Do you have any questions before this task begins? Let me know when you are complete.

Answer all questions. After the team states that they have completed detail design, the researcher distribute the goals of the manufacturing organization (Appendix D.3.1.2).

Remember that you are individually being evaluated on your ability to achieve the goals of your functional organization. At this time you can redesign your system considering the goals of the manufacturing organization. Let me know when you are complete.

After the team completes detail design, the researcher will distribute the goals of the support organization (Appendix D.3.1.3).

Remember that you are individually being evaluated on your ability to achieve the goals of your functional organization. At this time you can redesign your system considering the goals of the support organization. Let me know when you are complete.

At the conclusion of detail design, the researcher distributes the Final Design Review Form (Appendix D.3.2) to each individual.

Please write the stop time of detail design on your time card. Please compete the Final Design Review Form individually.

The researcher completes all fields on the Researcher's Log (Appendix D.6.1).

C.2.1.4. Manufacturing

Have the manufacturing member(s) of the team build the system.

Please write the start time of manufacturing on your time card. At this time the manufacturing member(s) of your team should build the system. Please let me know when you are complete.

When the manufacturing process is completed the team is convened to determine any design or manufacturing errors. These are written on the Design Errors and Defects Form (Appendix D.4.1). Then the Test Readiness Review Form (Appendix D.4.2) is distributed.

Please determine if manufacturing has built the system according to your drawings and specifications. If there are errors or inconsistencies, please fill out the Design Errors and Defects Form.

The time required to manufacture the system is recorded by the researcher on the Researcher's Log (Appendix D.6.1).

Please write the stop time of manufacturing on your time card.

Distribute the Test Readiness Review Form (Appendix D.4.2).

Please complete the Test Readiness Review Form.

The researcher completes all fields on the Researcher's Log and takes a photograph of the system.

C.2.1.5. Testing

Please write the start time of testing on your time card.

The team conducts the experiment using the team's design three times. If the system succeeds all three times, the experiment for robustness is conducted three times using a golf ball rather than a ping-pong ball. All results are logged on the Researcher's Log (Appendix D.6.1). The Life-Cycle Cost Form (Appendix D.5.1) and the Final Project Review Form (Appendix D.5.2) are completed.

Please write the stop time of testing on your time card and complete a final Life-Cycle Cost Form. Please complete the Final Project Review Form and attach all other documents from your team to it and give it to me.

Distribute the Individual Post-Experiment Questionnaire Form (Appendix D.5.3).

Please complete the questionnaire and give it to me.

After all questionnaires are received the researcher will distribute the Team Post-Experiment Questionnaire Form (Appendix D.5.4).

At this time we will complete the same questionnaire again but as a team. Please discuss among yourselves the best team answer to each question. Thank you very much for participating in this experiment. I will let you know how your team ranked after all of the experiments are complete.

The researcher completes all fields on the Researcher's Log (Appendix D.6.1), takes a photograph of the system, and turns off the videotape.

C.2.2. Concurrent Engineering With (CC) and Without Computer Support (CC)

C.2.2.1. Conceptual Design

Please log the start time of conceptual design on your time card. The purpose of conceptual design is simply to reach agreement on a feasible approach. You should try to work as quickly as possible since you will only have a maximum of 60 minutes for this task.

The following only applies to conditions with computer support.

In this experiment we are going to use a special kind of software called groupware to help you arrive at agreement. The software is quite easy to use. I will explain it as we go along.

When you have reached agreement on an approach and are ready to proceed to the next task, detail design, please let me know.

Distribute the goals of the design, manufacturing, and support organizations (Appendix D.1.4) to their members.

At this time, I'd like to distribute the functional goals of the design, manufacturing and support organizations. You are being individually evaluated on your ability to achieve the goals of your functional organization. Remember to let me know when you've reached agreement.

Lead the Groupware process. Prior to beginning the session, ensure that the ideas and voting from a previous session have been cleared. Log the moderator and participant stations on by clicking on the GroupSystems Icon. Enter each login name and password. Click on "Folders" on the moderator station. Prior to the participants arrival, an agenda has been created with two tasks: a Categorizer activity and a Vote activity. Open the folder called "Joe's Experiment" and select the Categorizer activity at the leader station. Make sure that the previous lists at each participant station have no entries and that Group Settings have been set to allow participants to View Results. From the Agenda menu choose Join Activity by clicking on the Running Man icon. From the Group menu, choose Start Participants by clicking on the Pointing Hand icon. Select the participants to be started then close the dialog box by choosing OK. Confirm that all participants have an idea generation screen. Click on the Categorizer menu choice, then Open Private List. State the following to the group:

While using the groupware tool you may not talk among yourselves. On your workstations, please click on Categorizer, and then Open Private List. You can now type in your ideas for moving the ball across the hurdle. Click on Add, type in an idea, and then click on the save button to make a list of as many ideas as you wish. After you are through entering ideas, click on Close and let me know. You will have a maximum of 10 minutes to create ideas.

After all participants have ended creating ideas, collect the ideas to the public list.

At this time I would like you to mark all of the items that you would like to submit to the group by clicking on the item while holding the shift key down. Then click on Submit.

The researcher collects the ideas by clicking on Categorizer and Collect Ideas.

After the items have been collected, then click on Close. Other's ideas that you have not read will show up on your screen with a red exclamation mark.

You can enter comments about other's ideas by selecting the item on which you want to comment by clicking on the Eyeglasses icon. You many then add comments about the idea. After you have entered a comment, please click on the Submit button and your comments will be sent to your team members for their review. The number before the slash will show the number of comments that have been submitted. The number after the slash will be red if you have not read a comment.

After you have exhausted all of your ideas or comments on other's ideas please let me know. We will then vote and rank order the ideas. Please start submitting ideas now.

When everyone has signaled that they are done, from the leader's Group menu, choose Stop Participants by clicking on the Hand icon. Select the participants that you want to stop, then choose OK to close the dialog box.

From the leader's Group menu, choose Shift Activity by clicking on the Arrows icon. From the Shift Data To option area, select Existing Agenda Activity and choose OK to close the dialog box. From the Vote menu, choose Select Voting Method by clicking on the Scale icon. Select Rank Order, then choose OK to close the dialog box. Choose Yes to switch to voting mode. Start participants by clicking on the Pointing Hand icon. Select participants then click on OK.

At this time you will select the item that you want to move by clicking and dragging it to the desired position in the list. Continue until the list is in the order that you prefer. From the vote menu, choose Cast Ballot. Then confirm that you are casting your ballot by clicking on Yes. Please let me know when you are complete.

After all ballots are cast, Start Participants and select View Results from the Vote menu so they can see the voting results on their screen by clicking on the Bar Chart icon.

Please click on View Results from the Vote menu. You may choose the idea that got the most votes or you may now discuss among yourselves which idea you would like to select as the concept for your design.

Print a report showing the results of the voting task by clicking on Close at the bottom of the moderator's screen, then File, and Reports. Click on the Plus sign and add Agenda, System Concept, Vote, and People. Print a copy of the list of ideas with comments before exiting GroupSystems. When finished with GroupSystems close the voting activity. Click on File and Exit confirming that you wish to exit GroupSystems. Be sure to terminate and log-out all participants stations.

The following applies to conditions without computer support.

We will use the nominal group technique to reach agreement. Let's do a brief tutorial on the nominal group technique or NGT. There are five steps in a NGT process. The first step is for each person to silently write down their ideas. The next step is to write down everyone's ideas on the wall in a round-robin manner with no discussion of each idea. The third step is to combine and clarify ideas. The fourth stage of NGT provides an opportunity for individual voting on the ideas. The fifth step is that after we've voted we'll discuss the results and make sure that everybody supports the result. I think that you will see that NGT is quite easy to do, even if you haven't done it before.

Distribute the goals of the design, manufacturing and support organizations (Appendix D.1.4).

At this time, I'd like to distribute the functional goals of the design, manufacturing, and support organizations. You are being individually evaluated on your ability to achieve the goals of your functional organization.

Lead the NGT process.

Let's begin the nominal group technique process. Without talking, individually write down on your notepad a list of concepts for systems that could achieve the system requirements. When you're done, please let me know and we'll go on to step 2.

When the group says that it is complete or a maximum of 10 minutes passes, begin step 2.

I would now like to record your ideas on the whiteboard taking one idea from each of you at a time until all of the ideas are posted. We will not challenge any of these ideas and we will eliminate duplicates.

Record all ideas, then begin step 3.

Now that all of the ideas are posted, let's discuss them. All of you must agree to any changes that we make to a concept.

Once the list has been completed, begin step 4 voting.

Now that we have the final list, let's vote on which idea has the most support among the group. I'd like you to write down your top five ideas and give 5 points to the best idea, in your opinion, and 4 points to the next best, and so on. After you're done, we'll write the points up here on the board.

Record the votes and note the group's highest ranking decision. Begin step 5.

The final step is for the group to decide whether the decision that you arrived at using the NGT process is the one that you want to use. Please discuss among yourselves if you want to use this decision or pick another one from the list. Please let me know when you've reached agreement and are ready to proceed to detail design.

The following applies to all concurrent conditions.

When the group says that it has reached agreement, have them complete the Design Concept Form (Appendix D.1.5), the System Concept Diagram (Appendix D.1.6), and the Preliminary Design Review Form (Appendix D.1.7).

Please select one person to complete the Design Concept Form. Select one person to draw a top-level sketch of the system on the System Diagram Form.

Conceptual design is now complete, please write the stop time on the time card. Then, please complete the Preliminary Design Review Form individually.

The researcher completes all fields on the Researcher's Log (Appendix D.6.1). Restart Participant 3 so they can access the life-cycle cost template.

C.2.2.2. Exercises

At this time we will conduct three exercises to make sure that the design people know how to use AutoCAD, the manufacturing people know how to put LEGOs together and read a three-view drawing, and the support people know how to use the EXCEL life-cycle cost spreadsheet.

These exercises are not part of the experiment so if you encounter any problems, please let me know as soon as possible so we can get them resolved.

See Section C.3.1 for a description of the learning objectives of the exercises. Conduct AutoCAD tutorial (Appendix D.2.1) by distributing tutorial instructions.

Please complete this tutorial on AutoCAD.

Time the tutorial. Review the drawing to make sure that it is correct. Repeat the exercise until the drawing is accurate. Conduct the LEGO Assembly Tutorial (Appendix D.2.2) by distributing tutorial instructions.

While your designer is working with AutoCAD, I would like to conduct another experiment to measure how long it takes you to assemble a system given the parts and a three-view drawing. Here is a bag of parts that can be assembled into the car shown in your drawing. I will time how long that it takes you to put it together correctly.

Time the assembly experiment. Conduct the life-cycle cost tutorial (Appendix D.2.3) by distributing tutorial instructions.

While the other exercises are in process, I would like to conduct an exercise in the calculation of life-cycle cost.

Time the LCC tutorial. When all tutorials are satisfactorily complete conduct detail design.

C.2.2.3. Detail Design

We are now ready to begin the detail design task. Please write the start time of detail design on your time card.

The purpose of this task is to convert your idea to a design that can be built using LEGOS. A measure of your team's performance is how accurate and complete your instructions are. If the manufacturer makes mistakes, it will count against your team's performance, so be as clear as you can be.

You may provide your instructions in the form of drawings, sketches, and/or text descriptions. Your instructions can also be in the form of dimensions and/or identification of individual pieces.

You must use the AutoCAD computer-aided design package to create a one-view drawing of the subsystem that interacts initially with the ball.

Distribute the goals of the design, manufacturing, and support organizations (Appendix D.3.1).

At this time I will distribute the goals of the design, manufacturing, and support organizations. Remember that you are being individually evaluated on your ability to achieve the goals of your functional organization. During this task you may not build the entire system but you can build components, subsystems, or prototypes to check out your approach. This task will be complete when you finish a one-view CAD drawing, and supporting sketches of other views of your system. Do you have any questions before this task begins? Let me know when you are complete.

Answer all questions. At the conclusion of detail design, the researcher distributes the Final Design Review Form (Appendix D.3.2) to each individual.

Please write the stop time of detail design on your time card. Please compete the Final Design Review Form individually.

The researcher completes all fields on the Researcher's Log (Appendix D.6.1).

C.2.2.4.   Manufacturing

Have the manufacturing member(s) of the team build the system.

Please write the start time of manufacturing on your time card.

At this time the manufacturing member(s) of your team should build the system. Please let me know when you are complete.

When the manufacturing process is completed the team is convened to determine any design or manufacturing errors. These are written on the Design Errors and Defects Form (Appendix D.4.1). Then the Test Readiness Review Form (Appendix D.4.2) is distributed.

Please determine if manufacturing has built the system according to your drawings and specifications. If there are errors or inconsistencies, please fill out the Design Errors and Defects Form.

The time required to manufacture the system is recorded by the researcher on the Researcher's Log (Appendix D.6.1).

Please write the stop time of manufacturing on your time card.

Distribute the Test Readiness Review Form (Appendix D.4.2).

Please complete the Test Readiness Review Form.

The researcher completes all fields on the Researcher's Log and takes a photograph of the system.

C.2.2.5. Testing

Please write the start time of testing on your time card.

The team conducts the experiment using the team's design three times. If the system succeeds all three times, the experiment for robustness is conducted three times using a golf ball rather than a ping-pong ball. All results are logged on the Researcher's Log (Appendix D.6.1). The Life-Cycle Cost Form (D.5.1) and the Final Project Review Form (Appendix D.5.2) are completed.

Please write the stop time of testing on your time card and complete a final Life-Cycle Cost Form.

Please complete the Final Project Review Form and attach all other documents from your team to it and give it to me.

Distribute the Individual Post-Experiment Questionnaire Form (Appendix D.5.3).

Please complete the questionnaire and give it to me.

After all questionnaires are received the researcher will distribute the Team Post-Experiment Questionnaire Form (Appendix D.5.4).

At this time we will complete the same questionnaire again but as a team.

Distribute the team post-experiment questionnaire.

Please discuss among yourselves the best team answer to each question.

Thank you very much for participating in this experiment. I will let you know how your team ranked after all of the experiments are complete.

The researcher completes all fields on the Researcher's Log (Appendix D.6.1), takes a photograph of the system, and turns off the videotape.

C.3.1. Exercises

Three exercises are employed during the experiment: (1) AutoCAD, (2) an assembly exercise using LEGOS, and (3) a life-cycle cost exercise. The purpose of these exercises is to ensure that a baseline level of expertise exists. The script for the exercises is contained in the experimental instruction section. The written instructions are contained in Section D.13. The following sections provide an overview of each exercise and their instructional purposes.

C.3.1.1. AutoCAD Exercise

The AutoCAD exercise consists of developing a two-view drawing of a wheel and axle assembly. The exercise demonstrates:

- How to look up a desired part on the parts list to determine the CAD name of the part.
- How to retrieve the part from the object library.
- How to orient the part in two-dimensional space relative to another part.
- How to dimension an assembly.
- How to print out a drawing.

C.3.1.2. Assembly Exercise

The assembly exercise consists of building a system given a set of parts and a three-view drawing of the system. The system to be assembled is shown in Drawing 9 of Appendix E, The LEGO Reference Drawing Package. The exercise demonstrates:

- How to read a drawing and interpret hidden lines.
- How LEGO pieces snap together.
- How a motor assembly works.

The following LEGO pieces are used in this exercise:

- 1 Motor
- 4 1 ¼” tires
- 2 5” beams
- 1 Standard brick (5/8 x 1 ¼)
- 2 1 ¼” beams
- 4 Technical plates (5/8 x 1 ¼)
- 2 2 ½” axles
- 1 Bevel gear (24 teeth)
- 1 Gear (8 teeth)
- 3 Bushings

C.3.1.3. Life-Cycle Cost Exercise

The life-cycle cost exercise consists of calculating life-cycle cost using an EXCEL spreadsheet. The exercise demonstrates:

- How to access the file template for cost calculation.
- How to interpret labor and material costs.

- How to interpret spare and moving parts costs.

The data to be used for the exercise are as follows:

- Number of team members = 3
- Conceptual Design Labor = 25 minutes
- Detail Design Labor = 45 minutes
- Manufacturing Labor = 15 minutes
- Testing Labor = 10 minutes
- Moving Parts = 9
- Materials
    - 5/8 x 1 ¼ inch standard brick = 1
    - 3/8 x 5/8 inch standard brick = 1
    - Motor = 1
    - Gears = 2
    - 4 Wheels (Tires)
    - Plates with holes = 4
    - Axles = 2
    - 5 inch Beams = 2
    - 1 ¼ inch Beams = 2
    - Bushings = 3

Appendix D - Experiment Forms

D.1. Conceptual Design

D.1.1. System Performance Requirements Statement

THE "MISSION POSSIBLE" CASE

Your company has received a secret government contract to design, build, and test a transportation system. This system will be used to move a circular container of valuable material from behind enemy lines to friendly territory. A large barricade has been erected across the only road out by the enemy.

In order for your company to work on this project without attracting local attention a prototype is being build with toys. This prototype, if successful, will be used to secure funding to complete the actual system.

The requirements have been scaled from the real situation to requirements for the toy system. The toy system must move a ping-pong ball (i.e., circular container) from a starting point (i.e., current location) to a finish line (i.e., friendly territory). You may not touch the ball or the hurdle (i.e., barricade) at any time. The ball may be moved over or around the hurdle. You may not use human energy to move the ball. The ball rests on a LEGO piece (5/8" x 5/8" x 3/8") at the starting line.

You must be able to build the system that you design with LEGOS and the following materials: a roll of Scotch-brand tape, rubber bands, a 4" x 7" piece of cardboard, a calculator, #2 pencils, drawing paper and scissors.

Your design will be evaluated on several criteria such as how long the design process takes and how easy it is to build (producability). However, the most important criteria is whether it meets the performance specification (i.e., moves the ball to the finish line). You do not have an unlimited amount of time to complete this task. The government has offered an incentive bonus for early completion of the project.

Each one of you has been assigned to a functional organization --- either design, manufacturing, or support. Each functional organization has goals that will be given to you during the experiment that you should attempt to achieve. Individual performance will be a function of how well you achieve your functional goals.

The overall experiment will be divided into tasks and reviews. There are 4 tasks --- conceptual design, detail design, manufacturing, and testing. In the first task --- conceptual design, your team will reach consensus on an overall design approach for the system. You must use a nominal group approach in order to achieve consensus on a design approach. You will be trained in the nominal group approach that you will use.

In the second task --- detail design, your team will prepare instructions in the form of AutoCAD drawings or written descriptions that can be used to manufacture your system using LEGOS. You will also be asked to prepare a life-cycle cost estimate of the system.

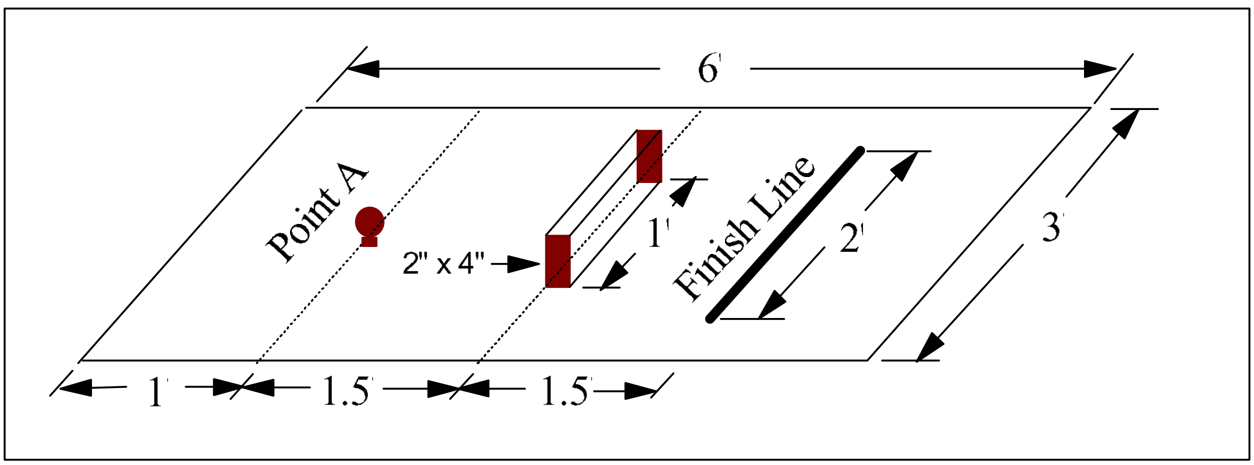
In the third task --- manufacturing, you will construct your system based on your team's instructions. Your system must match your drawings and specifications. If it does not, you will have to modify your drawings.

In the fourth task --- testing, your system will be tested to determine if it meets the performance specifications.

There are a number of reviews between the design tasks that will consist of questionnaires that you must fill out about the process you are using. They are simple and won't take but a few minutes to complete.

It is possible that the requirements for the toy system do not exactly simulate the requirements of the actual system. Therefore, your design should be as robust as possible. This means the design should still be capable of meeting the performance specifications given minor changes in the requirements. For example, our intelligence forces may be slightly incorrect in the exact location or height of the barrier, or the weight or size of the container.

Good luck, the Mission Possible force is counting on you. Remember, you may not discuss this top secret project with anyone that is not on your team.



D.1.2. Time Card and Exercise Log Form

TIME CARD

Team:		**Date:**
CONCEPTUAL DESIGN	Start Time:	
	Stop Time:	Minutes:
DETAIL DESIGN	Start Time:	
	Stop Time:	Minutes:
MANUFACTURING	Start Time:	
	Stop Time:	Minutes:
TESTING	Start Time:	
	Stop Time:	Minutes:
		TOTAL:
Round times to nearest minute.		# OF TEAM MEMBERS:
		TOTAL LABOR TIME:

EXERCISE LOG

AUTOCAD EXERCISE	Start Time:	
	Stop Time:	Minutes:Seconds:
MANUFACTURING EXERCISE	Start Time:	
	Stop Time:	Minutes:Seconds:
LIFE-CYCLE COST EXER.	Start Time:	
	Stop Time:	Minutes:Seconds:
Time in minutes and seconds.		

D.1.3. LEGO Tutorial

LEGO TUTORIAL

I'll bet that sometime in your childhood you had a chance to play with LEGOS. LEGOS are building blocks that come in a variety of sizes that can be used to build just about anything. The new LEGO sets have mechanical components like motors, pulleys, axles, gears, and other pieces that will permit you to build things that do work. The system that you are being asked to design must be built out of LEGOS.

Standard pieces are designed on dimensions that are multiples of 5/16th of an inch in length and width and 3/8ths of an inch in height. Each piece has little protrusions that are called studs that allow pieces to be assembled together.

Standard pieces come in widths of one stud or two studs. They come in a variety of lengths from one stud up to 16 studs. For the sake of terminology, we'll call pieces that have two rows of studs as "doubles" and one row of studs as "singles". You will be given a list of pieces that are available to you and the quantity of those pieces that can be used in the experiment.

Another type of standard piece is a plate. Plates can be either 1/8th inch or 3/8th inch thick. Plates are used as a foundation for a system or as a surface to span between pieces like a roof.

All LEGO pieces come in a variety of colors. Color makes no difference with respect to the use of a particular piece or to this experiment. So don't worry about matching or using specific colored pieces.

Unless you were extremely fortunate you probably didn't have a set of technical pieces to play with when you were a child. They are very expensive. They are typically used in advanced science programs in secondary schools to teach how motors, gears, pulleys, and other components work.

So let's look at some of these pieces to make sure that you understand how they work and how they can be assembled into a mechanical system.

I am attaching a reference drawing package that contains a number of pictures of the various LEGO pieces and how they can be assembled. These reference documents, that you can use during the experiment, should give you enough information to build a wide variety of mechanical systems.

Drawing 1 shows an axle and a beam. Axles are rods that come in a variety of lengths from 1 1/4th inches up to 3 3/4th inches long. Axles can be used to mount gears, pulleys, or wheels on.

Beams are pieces that have a single row of studs that have holes in them for axles to pass through them. They come in a variety of sizes from 5/8th inch to 5 inches.

Drawing 2 shows an example of an axle and beam being used as a wheel assembly. Note the use of the bushings to lock the axle in place.

Drawing 3 shows that bushings have two different ends. One end can be used to lock an axle and the other will allow the axle to rotate.

Drawing 4 shows the use of gears. Gears come in a variety of sizes from those having 8 teeth up to 40 teeth. We have normal gears, bevel gears that can be used with a differential to change the direction of a spinning axle, and two types of worm gears.

Drawing 5 shows the assembly of a differential. Differentials are used to change the plane of rotation like from the drive shaft of a car to an axle.

Drawing 6 shows a worm gear.

Drawing 7 shows how gears and pulleys can be connected to each other.

Drawing 8 shows how a motor can be connected to gears and pulley. Pulleys come in a 1" and 1 1/4th inch size. Pulleys are also used as wheels. In other words, a pulley that fits tightly around the hub is a wheel. The motor that is available is a 4.5 volt motor that can produce 6000 revolutions per minute (RPMs) on its output axle. The motor is powered by a three 1.5 volt batteries that are contained in a battery pack. The line connecting the motor to the battery pack is not very long so, if you use the motor, you may have to design the battery pack into your system.

There are also a number of miscellaneous pieces that you may need like connector pegs, bushings, pulleys, and rubber bands. Their use and function will be obvious in just a moment.

I would now like you to look at a series of pictures of systems that have been built using the technical pieces. Drawing 9 shows the construction of a small car using a motor driving wheels using gears. Drawing 10 shows the construction of a small car using a motor driving wheels using a worm gear.

Drawing 11 shows a small car in which the battery pack has been designed into the car.

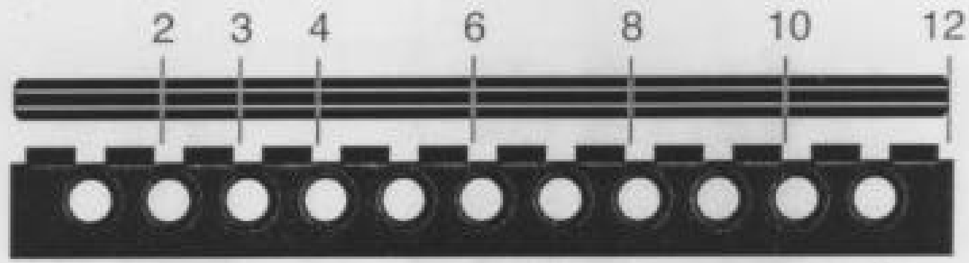
Drawing 12 shows that a bushing has two different ends. One end will allow the axle to rotate. The other end will lock the axle in place.

I will give you a booklet that contains a bill of material or a list of the pieces that you can use in your design. What you see on the list is all we have, so make sure that your design doesn't call for any pieces that we don't have or more of a particular piece than we have. The booklet also shows the CAD images associated with each file name. Note that each piece has a CAD name associated with a front, top, and end view of the piece. These are the symbol or object or entity names that have been stored in AutoCAD to permit you to rapidly draw, in two dimensions, each of these LEGO pieces.

D.1.3.1. LEGO Drawings[1]

[1] Drawings used with permission of the LEGO Group, Inc.

DRAWING 1



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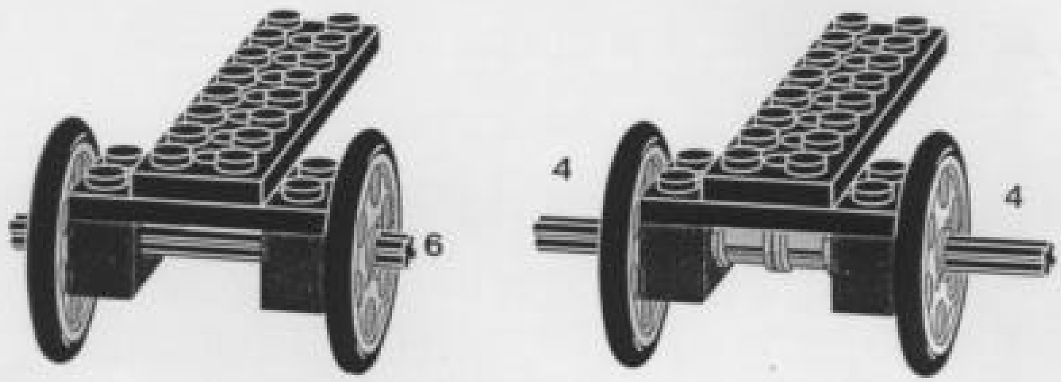
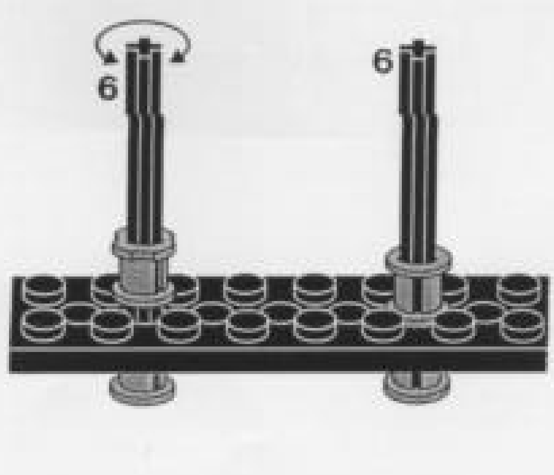


DRAWING 3



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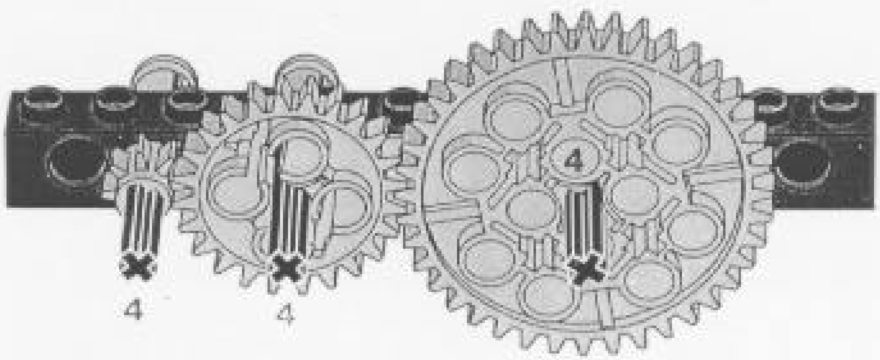

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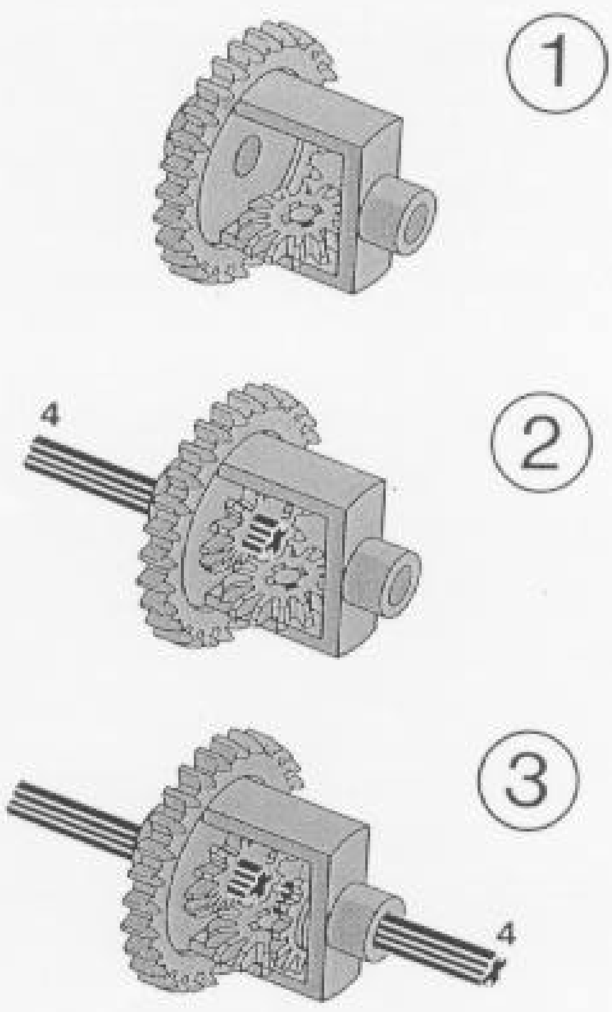

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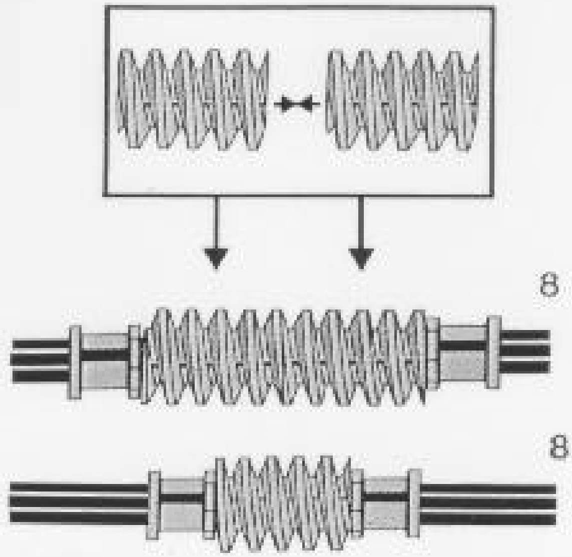

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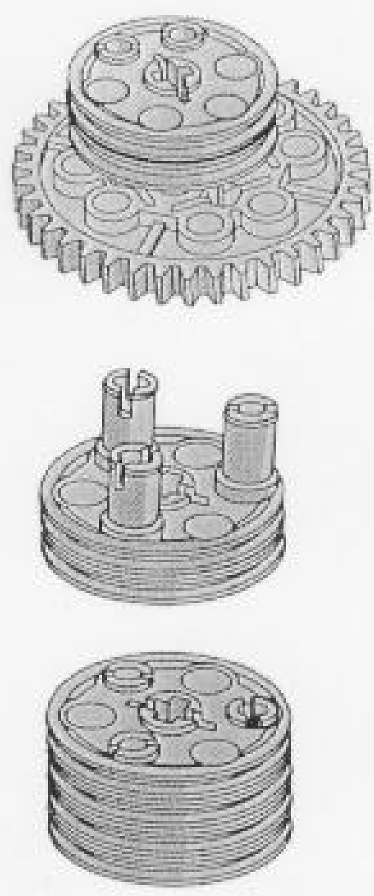

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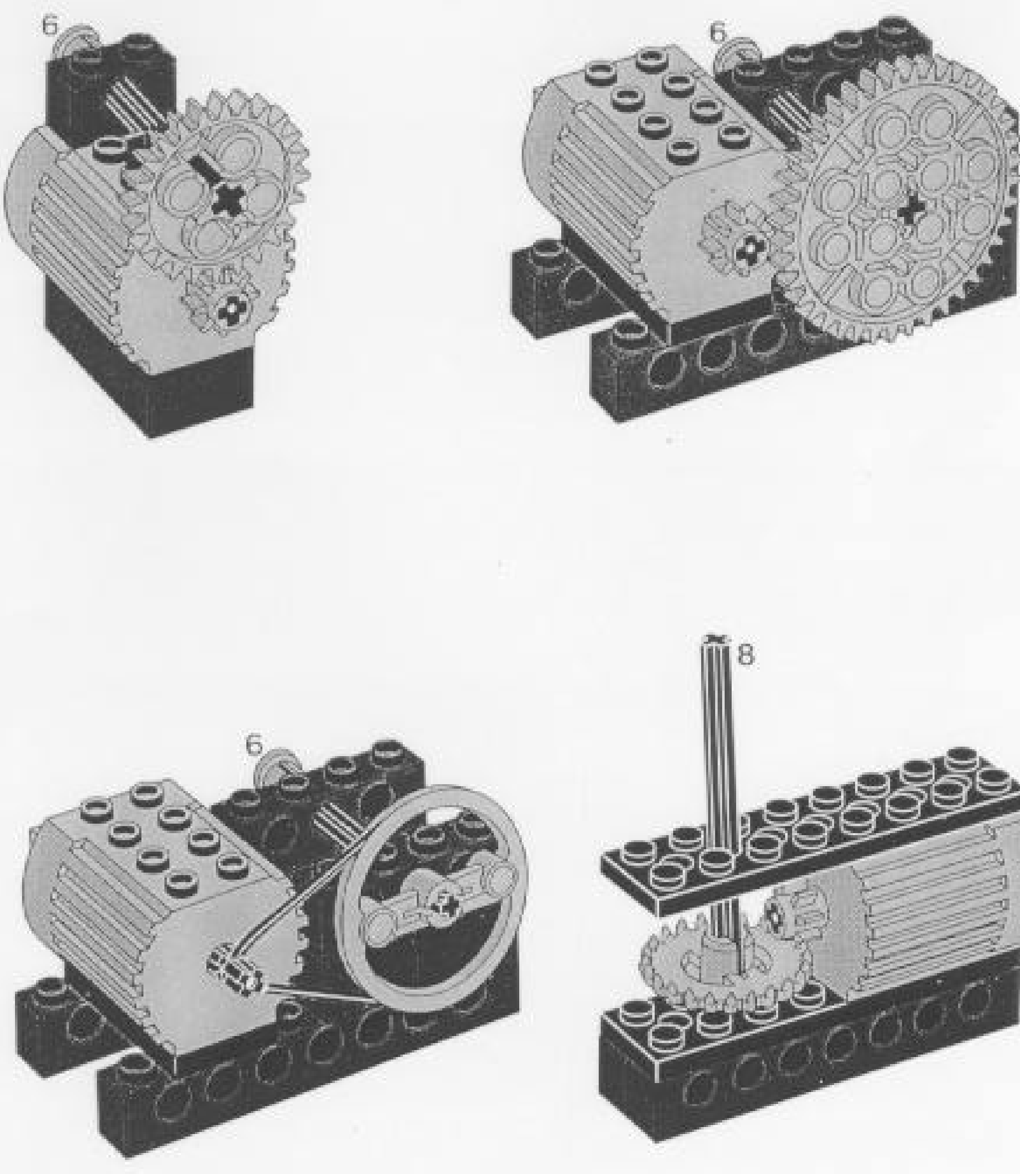
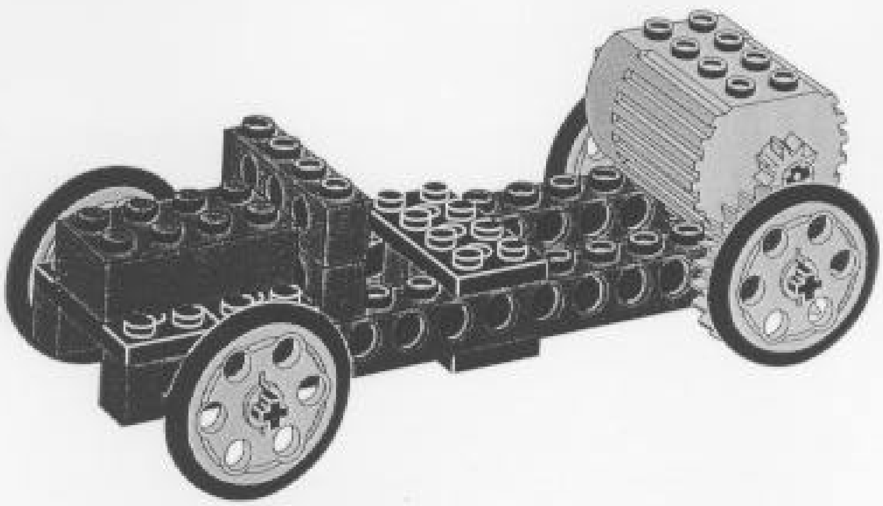
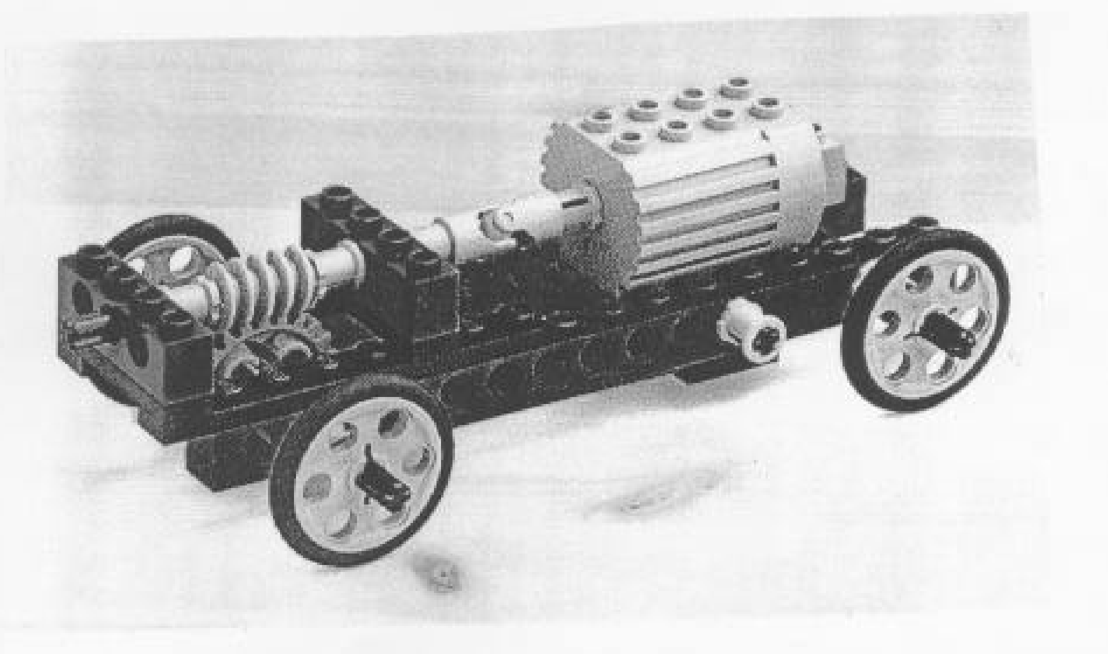


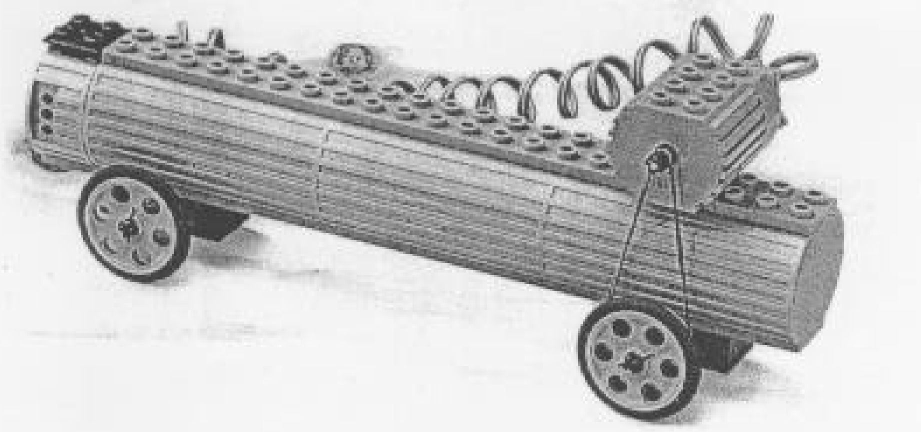
DRAWING 9



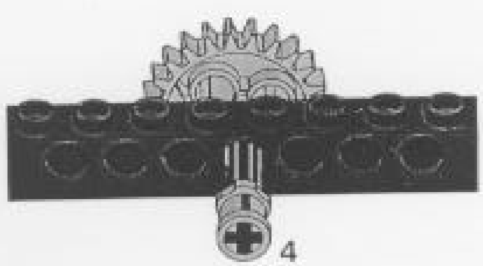
DRAWING 10



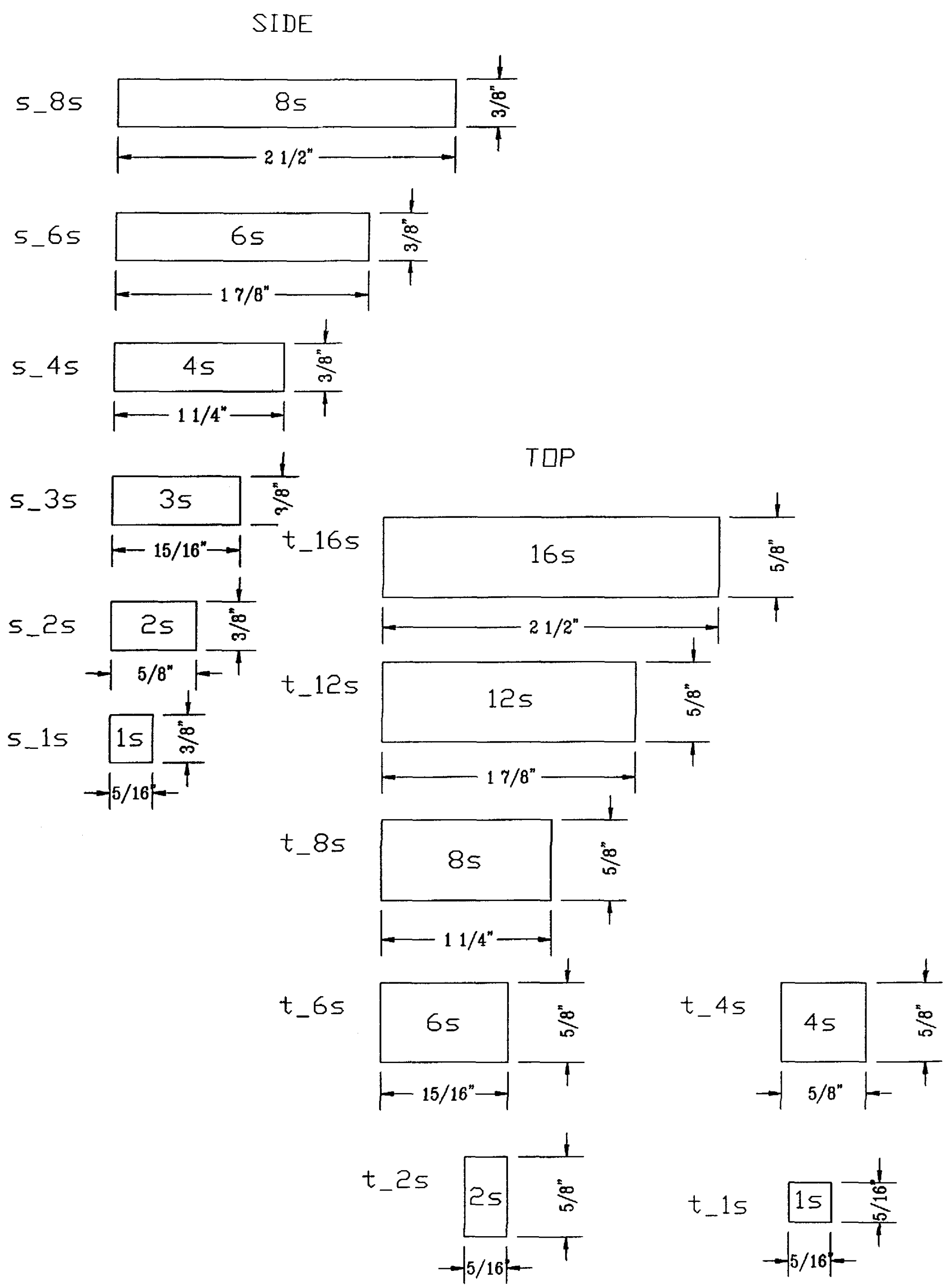
DRAWING 11

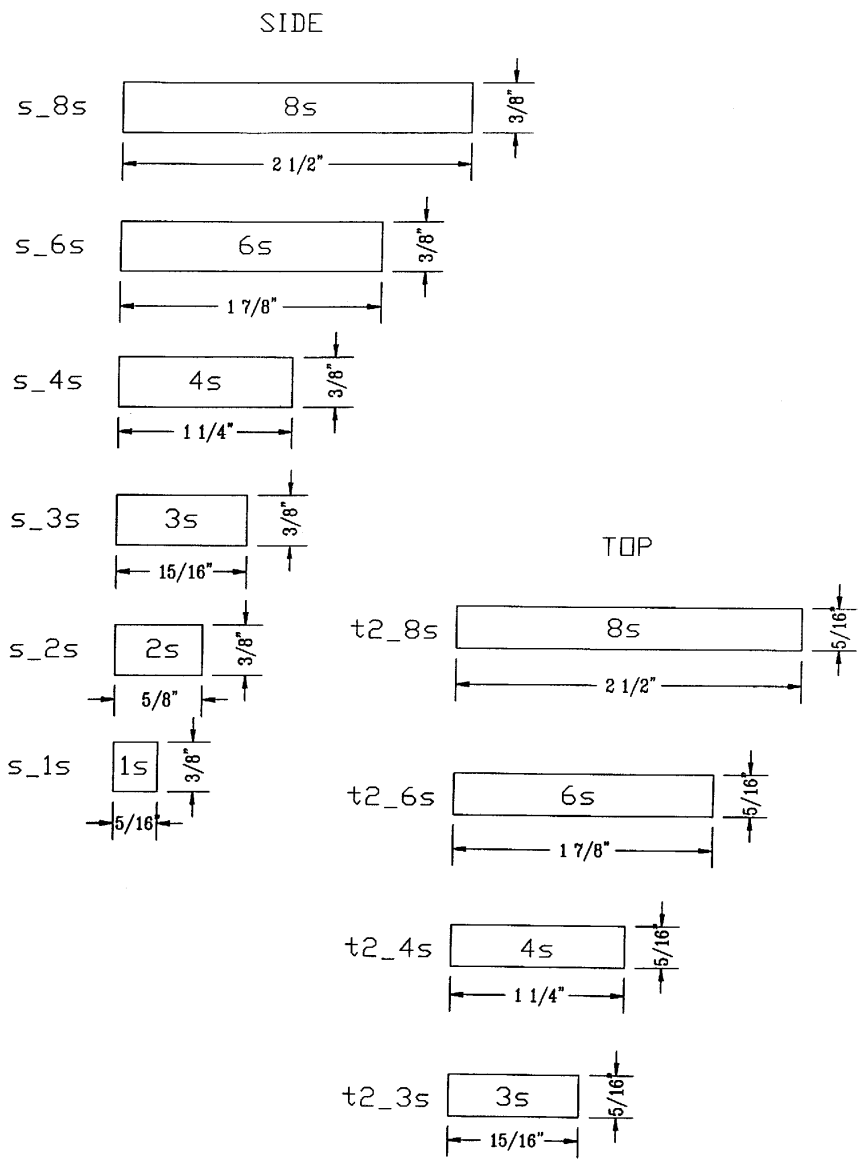


DRAWING 12



D.1.3.2. AutoCAD LEGO Blocks





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s_4s
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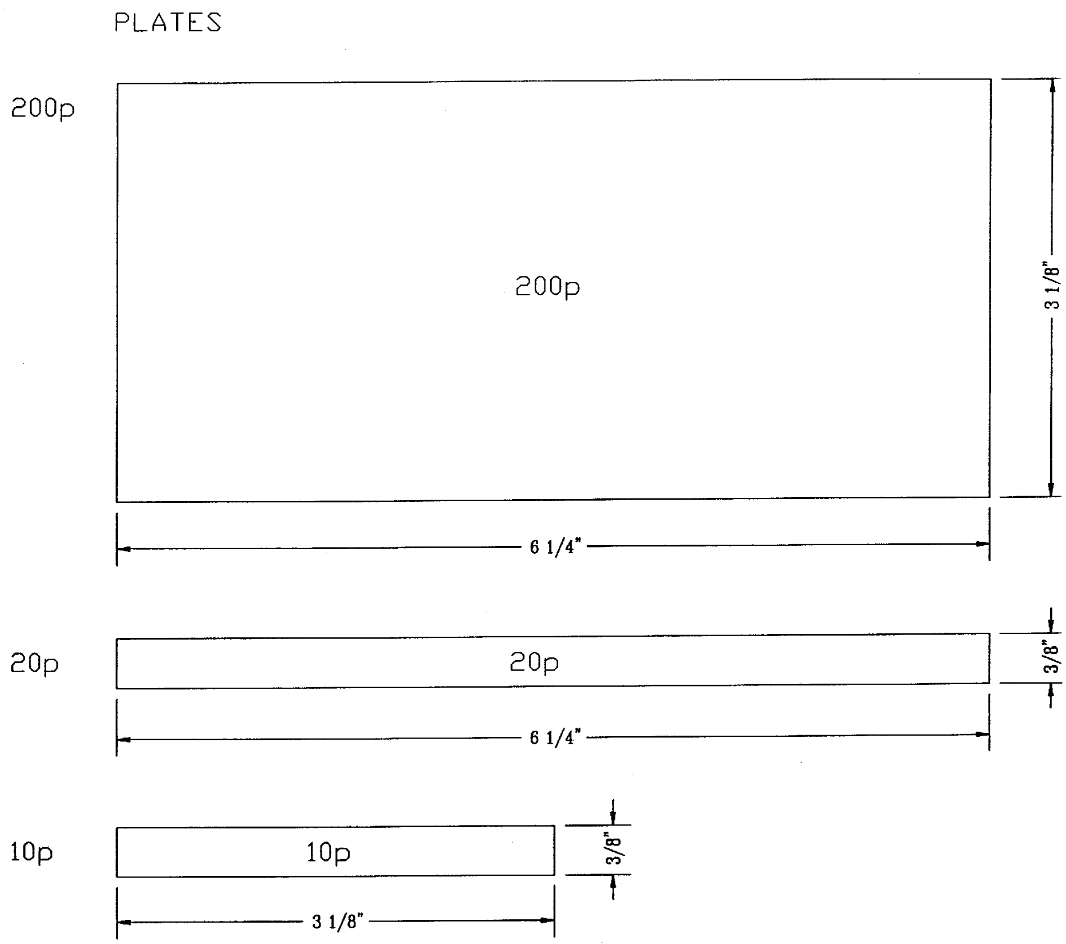
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6 1/4"
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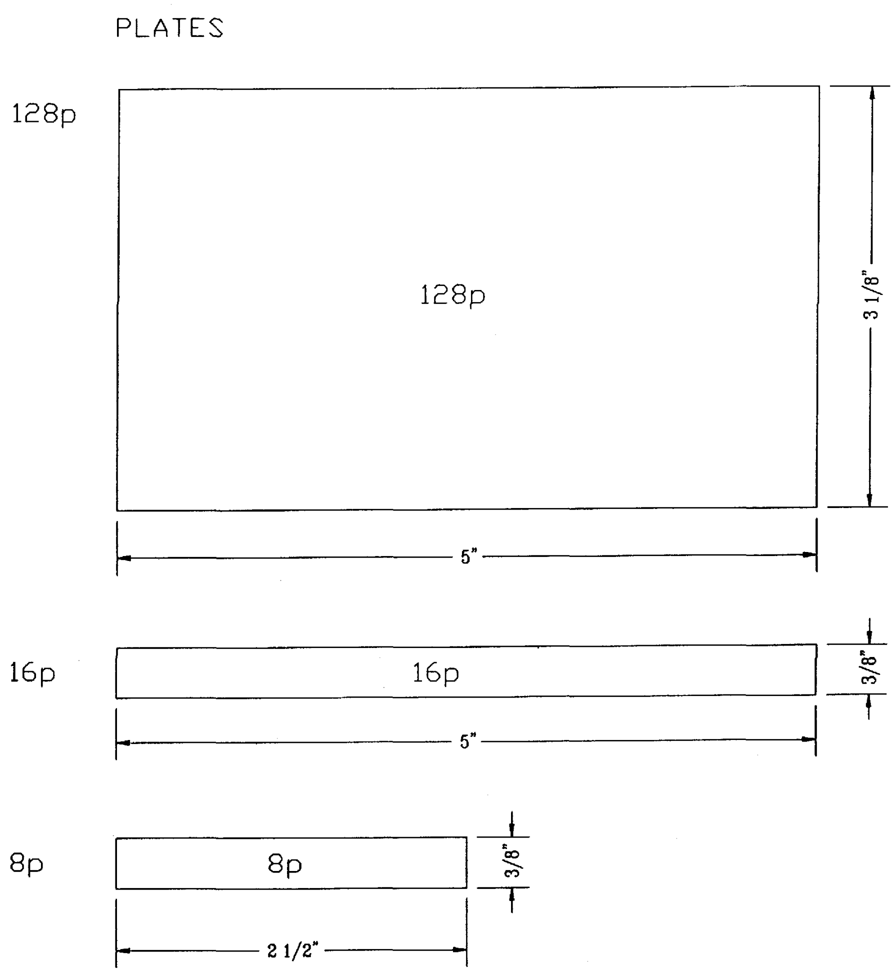
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3/8"
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8p
8p
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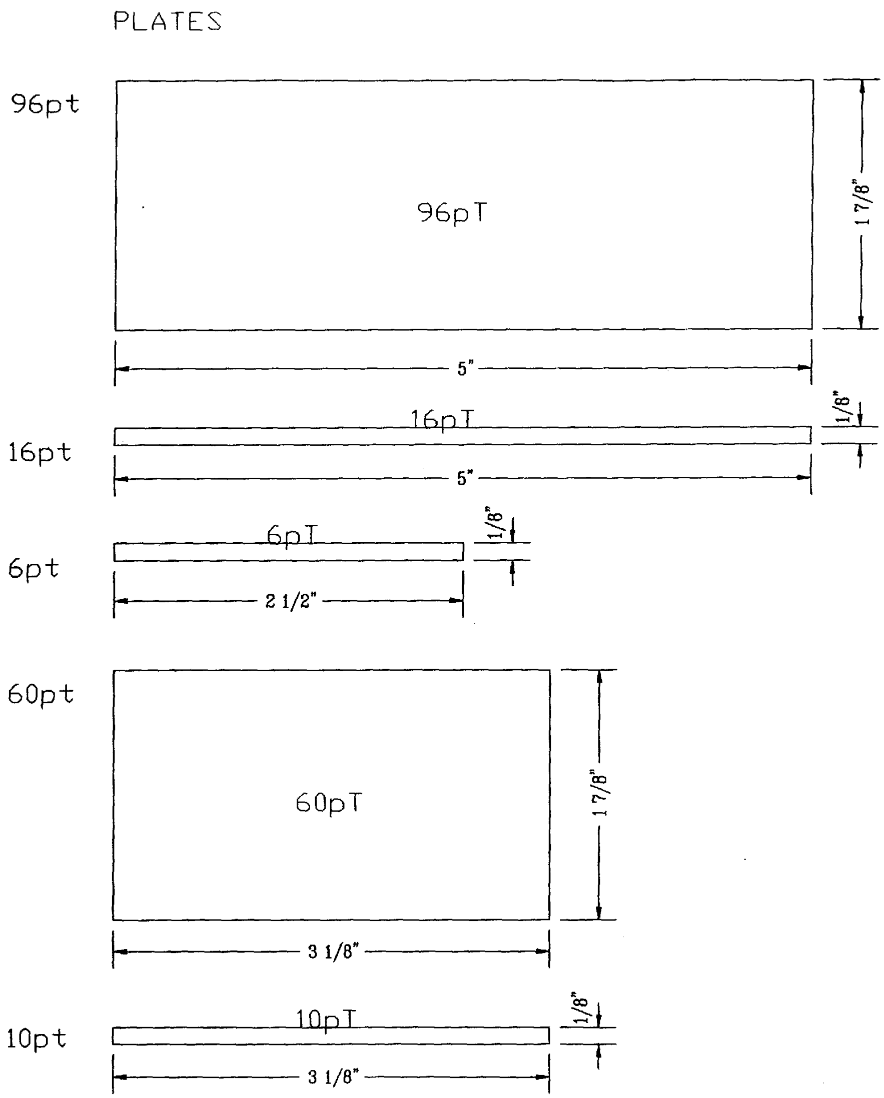
2 1/2"



PLATES
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16pT
16pt
1/8"
5"
6pT
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60pT
1 7/8"
3 1/8"
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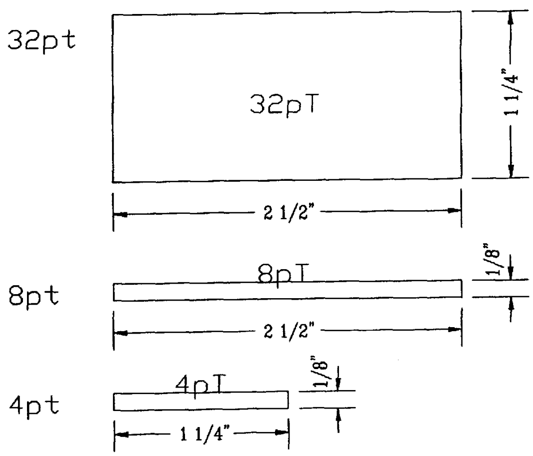
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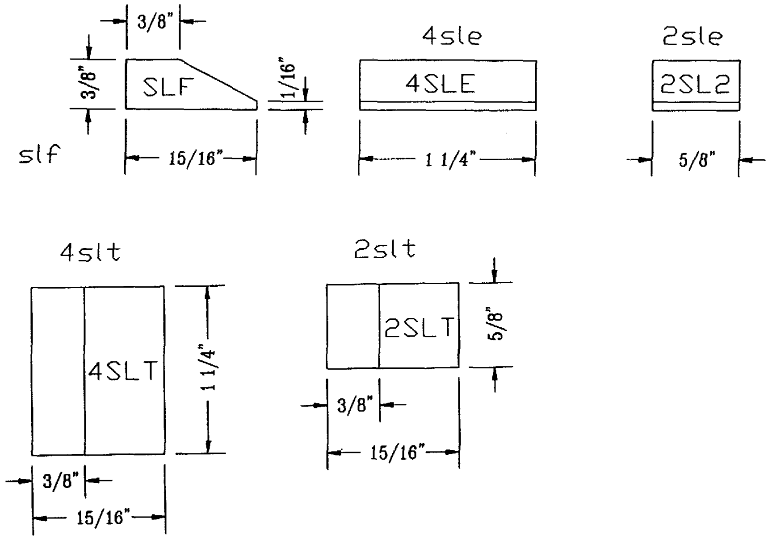
1 1/4"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4SLE
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2slt
2SLT
5/8"
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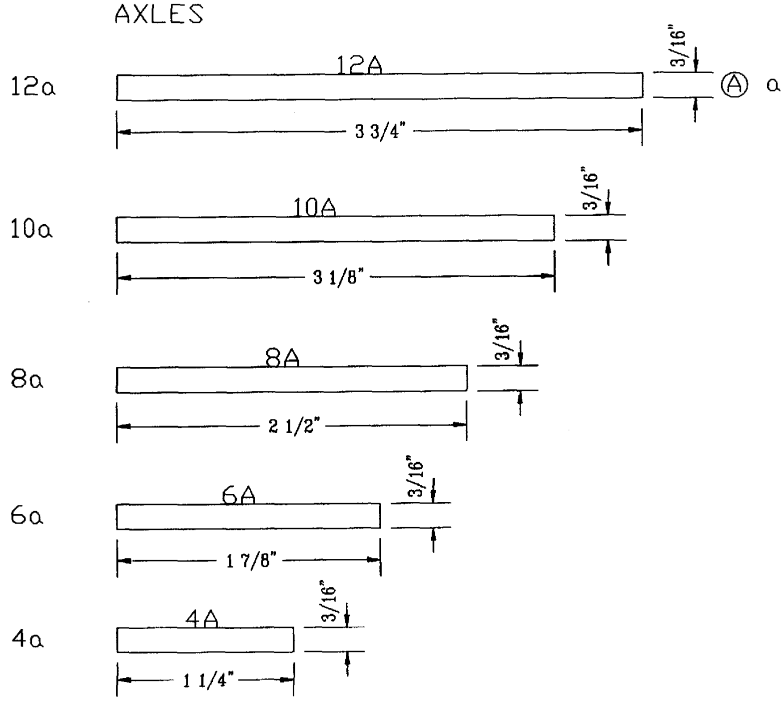
15/16"

AXLES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10a
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8A
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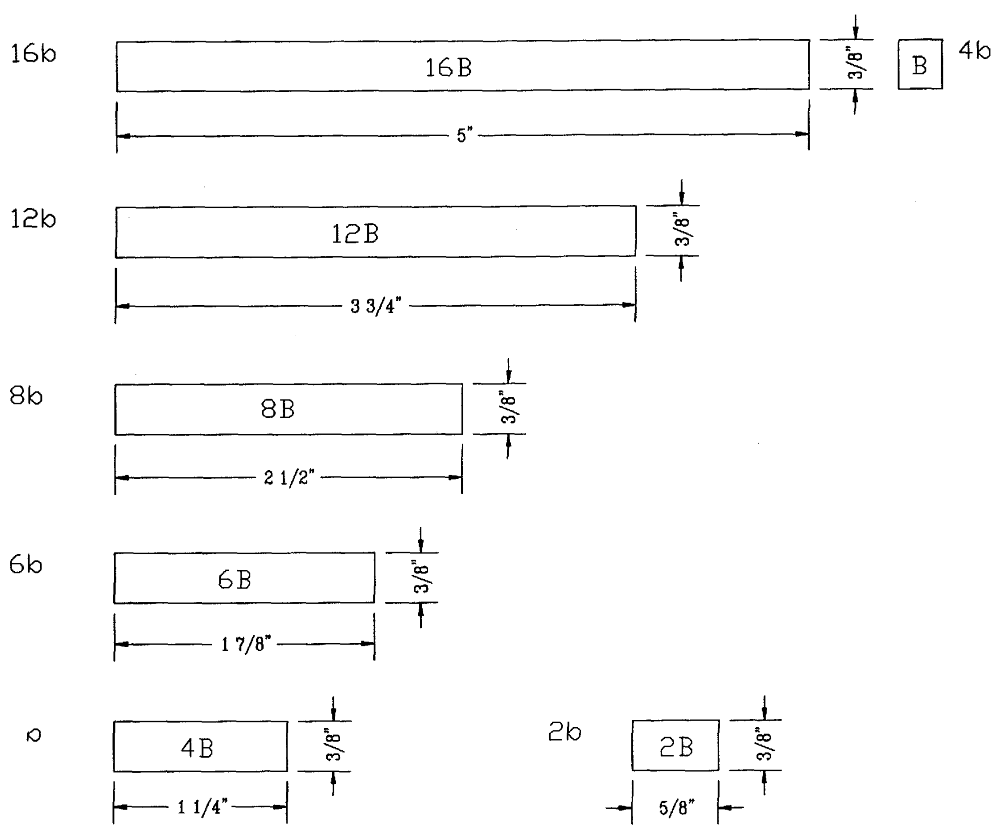
4A
1 1/4"
3/16"

BEAMS



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16B
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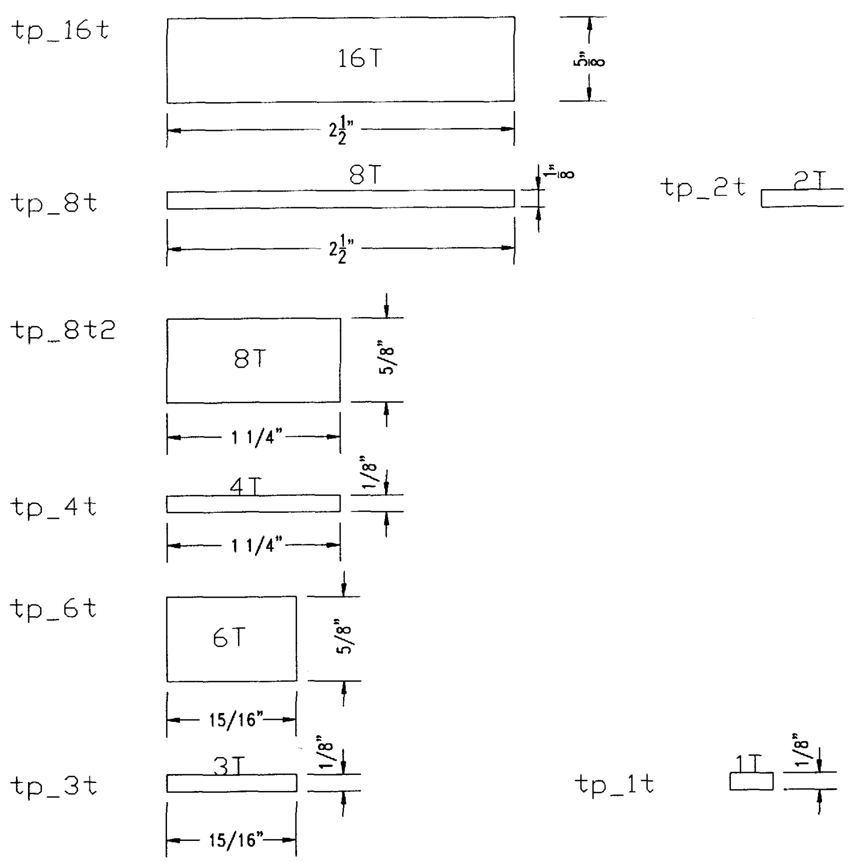
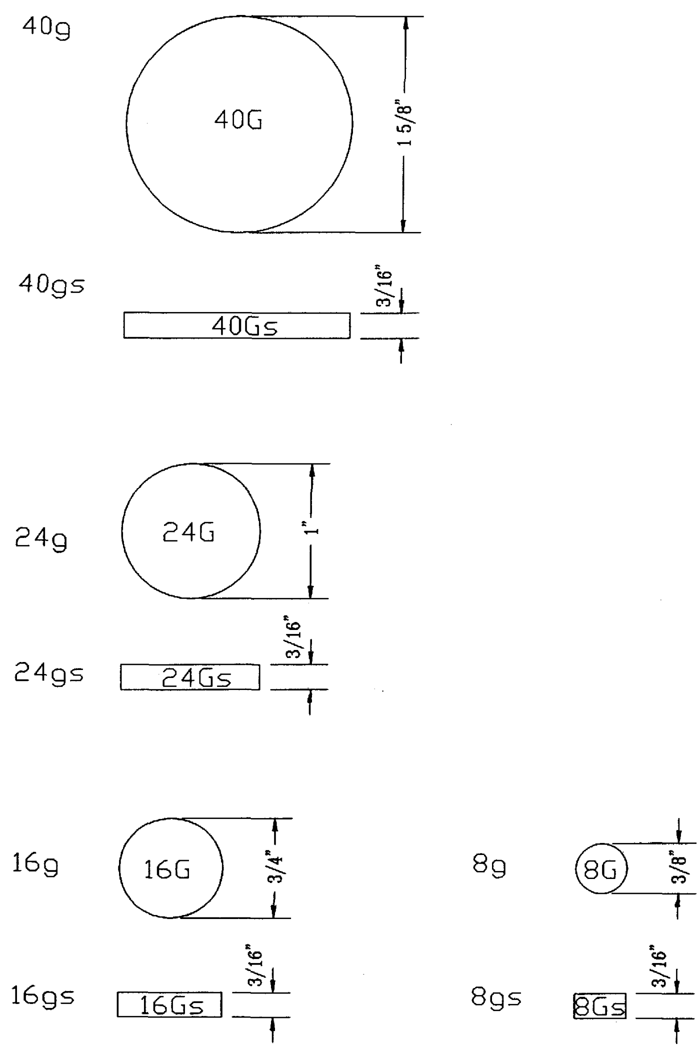
B
4b
5"
12b
12B
3/8"
3 3/4"
8b
8B
3/8"
2 1/2"
6b
6B
3/8"
1 7/8"
4B
3/8"
1 1/4"
2b
2B
3/8"
5/8"

TECHNICAL PLATES



GEARS


40g
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1 5/8"
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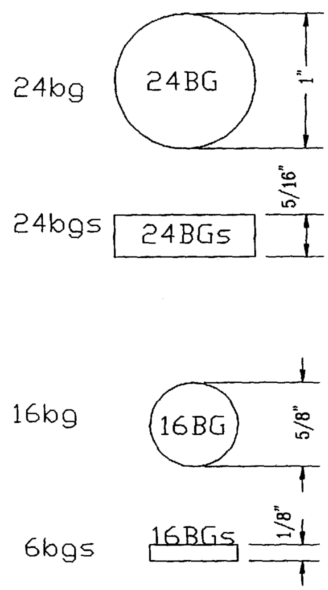
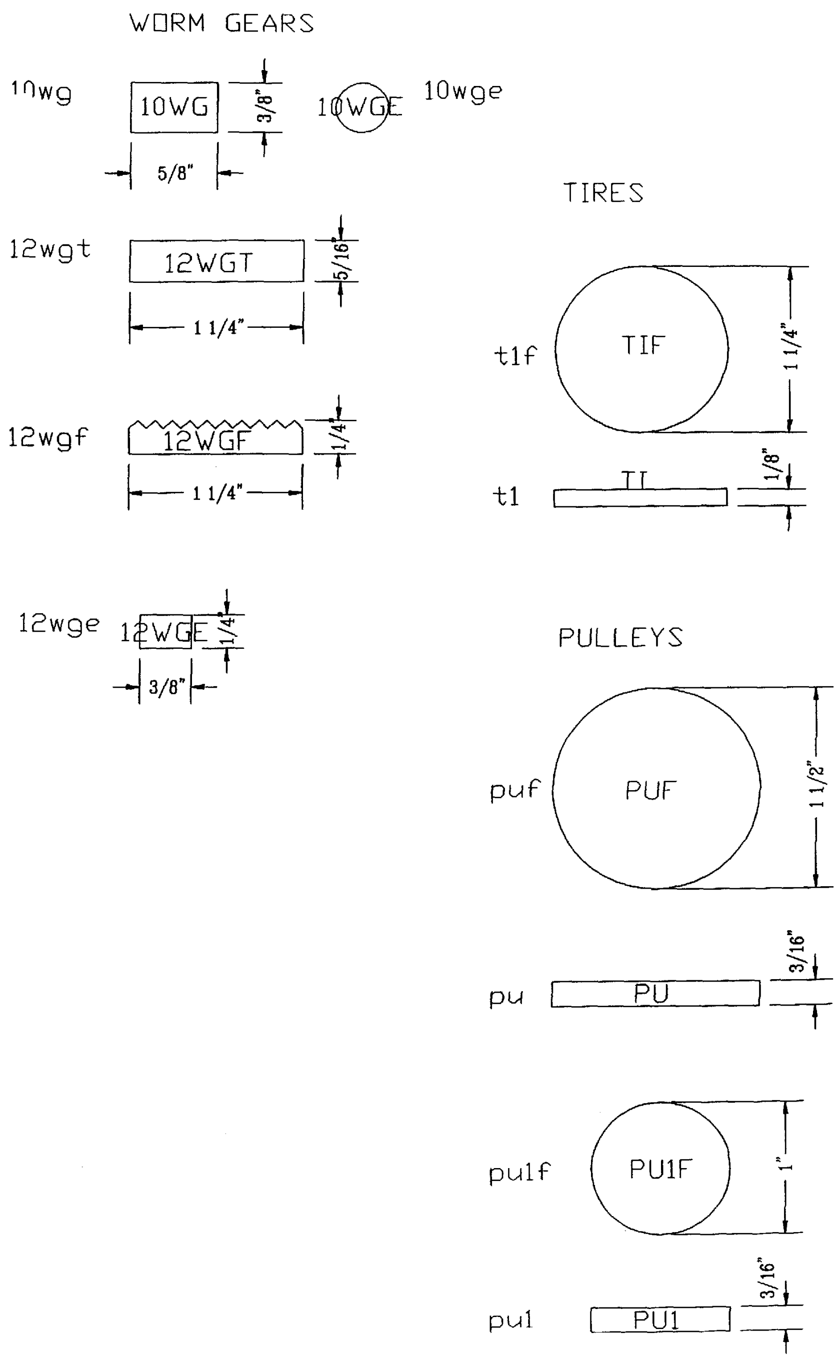
8G
3/8"
8gs
8Gs
3/16"

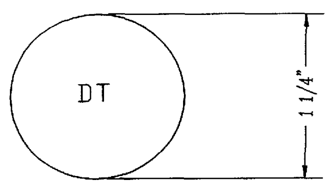
BEVEL GEARS



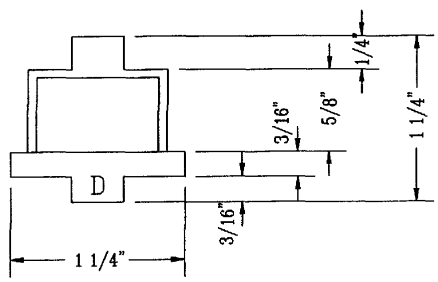

WORM GEARS
10wg
10WG
3/8"
5/8"
10WGE
10wge
12wgt
12WGT
5/16"
1 1/4"
12wgf
12WGF
1/4"
1 1/4"
12wge
12WGE
1/4"
3/8"
TIRES
t1f
TIF
1 1/4"
t1
TI
1/8"
PULLEYS
puf
PUF
1 1/2"
pu
PU
3/16"
pu1f
PU1F
1"
pu1
PU1
3/16"

DIFFERENTIAL

dt

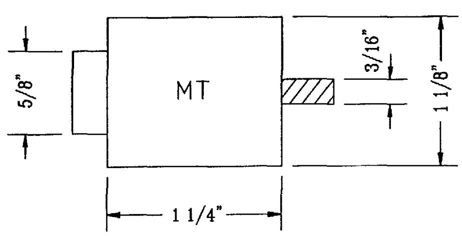


d

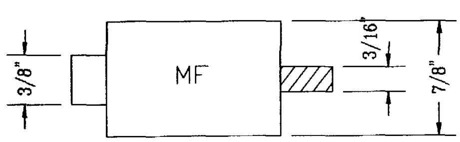


MOTOR

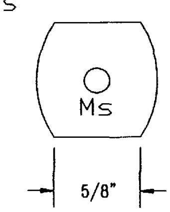
mt

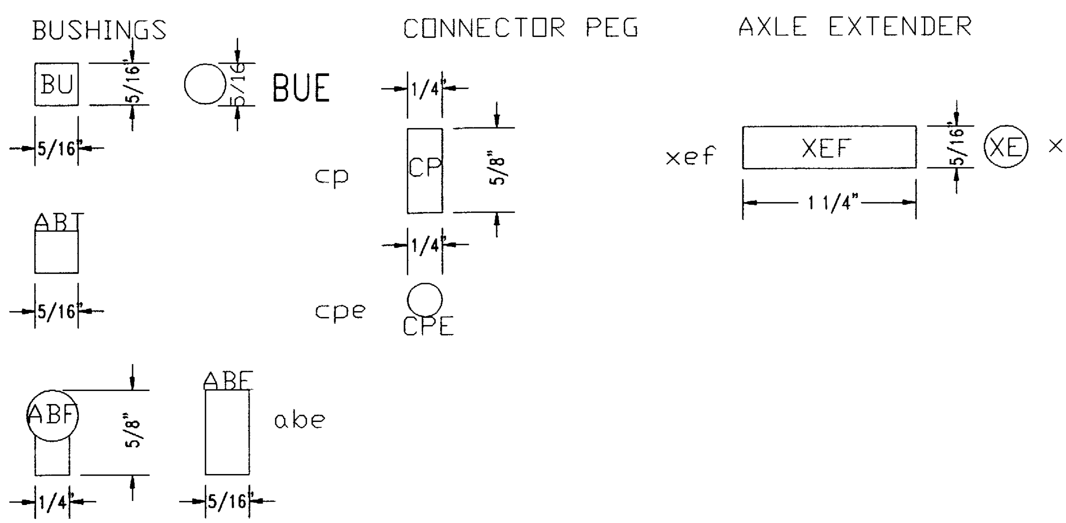


mf

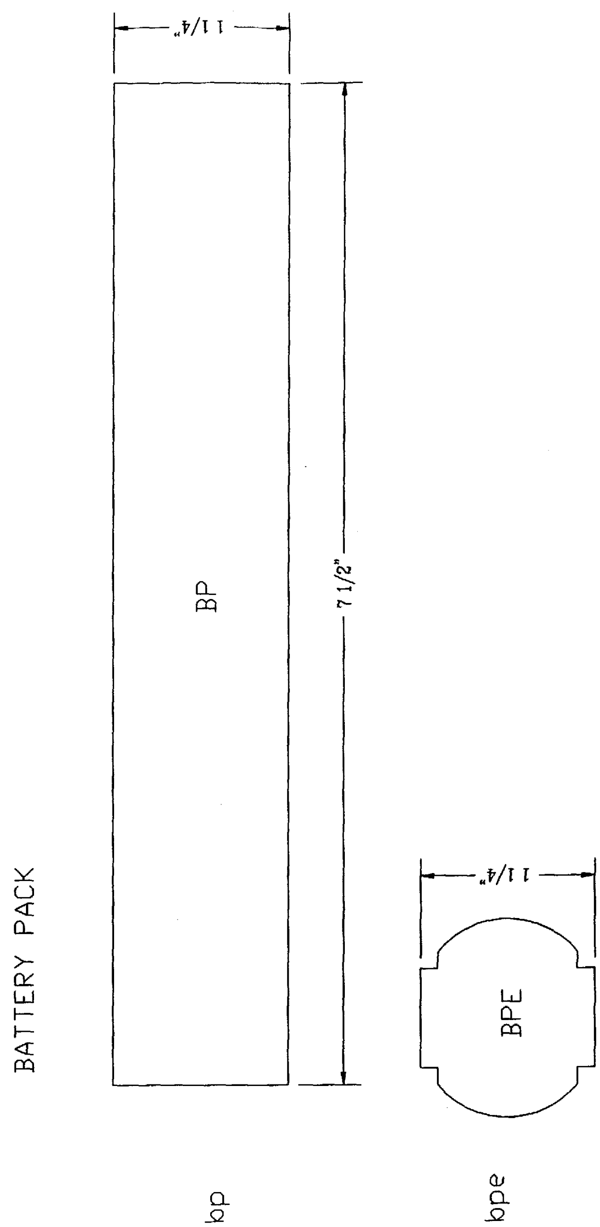


ms





BUSHINGS
BU
5/16"
5/16"
BUE
5/16"
ABT
5/16"
ABF
5/8"
1/4"
ABE
abe
5/16"
CONNECTOR PEG
1/4"
cp
CP
5/8"
1/4"
cpe
CPE
AXLE EXTENDER
xef
XEF
5/16"
XE
x
1 1/4"


BATTERY PACK
1 1/4"
BP
7 1/2"
bp
1 1/4"
BPE
bpe

D.1.4. Conceptual Design Functional Goals

D.1.4.1. Design Goals

A design organization has two primary goals during conceptual design. You should attempt to make sure that the conceptual design that you propose is as robust as possible. Robust means that the design will still work with minor changes in the specifications. Secondly, you should attempt to minimize the length of time that conceptual design takes.

D.1.4.2. Manufacturing Goals

Your manufacturing facility is limited in space. Your goal is to try to make the size of your system as small as possible. Size will be measured as the smallest volumetric box that will encompass the entire system.

D.1.4.3. Support Goals

Since your support organization will be responsible for the life-cycle maintenance of the system. Your goal is to minimize the number of moving parts.

D.1.5. Design Concept Form

DESIGN CONCEPT FORM

Team Name: ___________________ Date:______________

Please describe the design approach that your team has selected to achieve this task. You need not be too specific at this time.

____

____

____

____

____

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____

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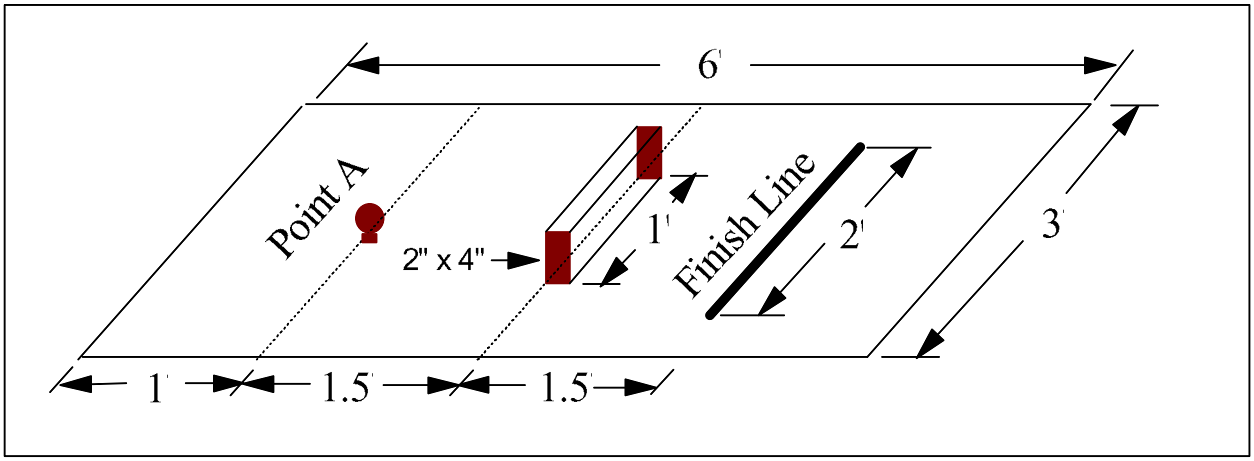
____

D.1.6. System Concept Diagram

SYSTEM CONCEPT DIAGRAM



D.1.7. Preliminary Design Review Form

PRELIMINARY DESIGN REVIEW FORM

Team Name: ___________________ Function: ____________________ Date:______________

SA	A	U	D	SD
strongly agree	**agree**	**undecided**	**disagree**	**strongly disagree**

1. There is no doubt that the system concept that we have developed will result in a system that meets its performance requirements.

SA A U D SD

2. No one on our team has emerged as the leader of the team.

SA A U D SD

3. The final design is a team effort representing contributions from all team members.

SA A U D SD

4. Each functional member of the team achieved his or her functional goals.

SA A U D SD

5. I fully support the team's decision on the system concept.

SA A U D SD

6. The interaction among our team members was outstanding with little conflict.

SA A U D SD

If your team used groupware, please answer the following:

7. Groupware was easy to use.

SA	**A**	**U**	**D**	**SD**

8. Groupware greatly improved the efficiency of the team's process to define a concept.

SA	**A**	**U**	**D**	**SD**

9. Groupware greatly improved the effectiveness of the team's process to define a concept.

SA	**A**	**U**	**D**	**SD**

10. Groupware greatly improved the productivity of the team compared to other teams that I have been on.

SA	**A**	**U**	**D**	**SD**

11. Groupware greatly improved each member of the team's ability to contribute to the discussion.

SA	**A**	**U**	**D**	**SD**

12. Overall, I was extremely satisfied with the groupware process.

SA	**A**	**U**	**D**	**SD**

D.2. Tutorials

D.2.1. AutoCAD Tutorial Instructions

The purpose of this exercise is to demonstrate how to retrieve two-dimensional objects from a library of LEGO objects that has been created for your use. The exercise will also demonstrate that you know how to manipulate those objects, dimension a two-view drawing, and print it out. You must draw a two-view drawing of a wheel and axle as shown on the attached.

Step 1: Write the start time on the exercise log of your timecard.

Step 2: Click on the "Compass" AutoCAD icon at the participant 1 workstation.

Step 3: Open file "autotemplate." Then save this file as "autoex-(your initials)."

Step 4: Look up the object file names of the two parts on either the large chart or the booklet handout. The object file names of the axle are called "8A" and "A." The object file names of the wheel are called "T1F" and "T1."

Step 5: Note that the printable area of your file is a grid. Placing lines outside of this area will not print. Click on the insert block icon which is the second icon to the left of the "A" insert text icon. Click on "file." The LEGO objects are stored in file location: C:\r13\win\legos. Scroll to the file that you want and double click on it. If you need to retrieve multiple copies of the same part, you only need to type in the block name, not the file name. Click on OK. Place all four objects on your drawing grid. Figure 1 shows how the drawing should look at this point.

Step 6: Each object is dimensioned and labeled. Turn off the block dimensioning by clicking on Data and Layers, and turning off the layer for "texts". Also turn off the layer for Demline since you may want to dimension your system without the object dimensioning cluttering your drawing.

Step 7: Dimension the system using standard AutoCAD dimensioning features. Let the researcher know if you need any help with this step. The final drawing should look something like Figure 2.

Step 8: There are several approaches that you can use for changing continuous lines to hidden lines.

Option 1 - If an entire LEGO piece is hidden, you may select the object, click on the Properties icon and change the line type to hidden.

Option 2 - If a polyline of the object is hidden, you can click on the Explode icon and change the line type of the line segment to hidden.

Option 3 - If the interaction of the objects is complex, you may use liquid correction fluid to change the line to hidden after the drawing has been printed out.

Step 9: In order to print the system to the network printer, you must print your drawing to a file named “LPT2.” Click on the printer icon, click on file name, insert LPT2 as the file name and click on OK.

Step 10: Compare your drawing with the attached. If approximately the same, then write your stop time on the exercise log of the timecard. If not the same, ask the researcher for assistance.

Step 11: Calculate the total time of your exercise and write it on the timecard.

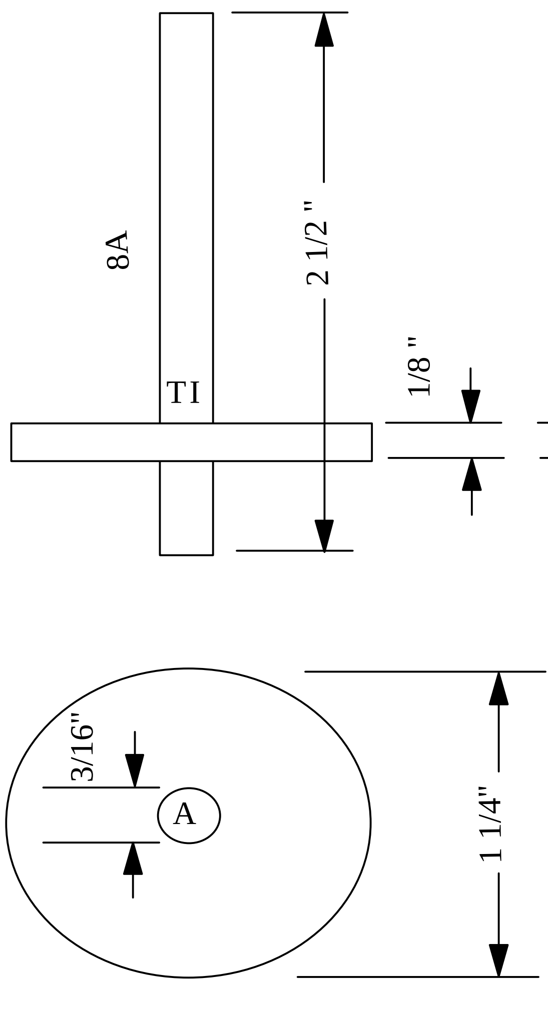


Figure 1

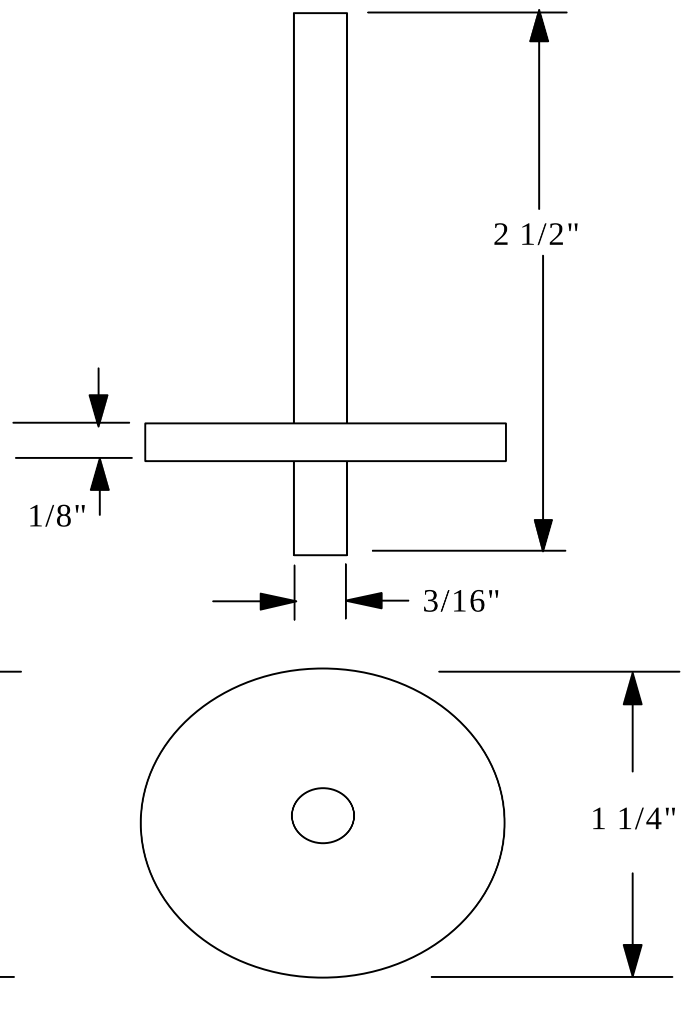


Figure 2

D.2.2. Assembly Tutorial Instructions

The purpose of this exercise is demonstrate that you know how to read a three view drawing. The exercise also will demonstrate one way of connecting a LEGO motor to an axle.

Step 1: Write the start time on the exercise log of your timecard.

Step 2: Verify that you have been given the following parts.

- 1 Motor
- 4 1 ¼" tires
- 2 5" beams
- 1 Standard brick (5/8 x 1 ¼)
- 2 1 ¼" beams
- 4 Technical plates (5/8 x 1 ¼)
- 2 2 ½" axles
- 1 Bevel gear (24 teeth)
- 1 Gear (8 teeth)
- 3 Bushings

Step 3: Using the attached three view drawing, please assemble the car.

Step 4: When you are complete, please notify the researcher to verify that the car is assembled correctly.

Step 5: Write the stop time on the exercise log of your timecard.

Step 6: Calculate the total time of your exercise and write it on the timecard.

D.2.3. Life-Cycle Cost Tutorial Instructions

The purpose of this exercise is to demonstrate how to use the life-cycle cost template which is an EXCEL spreadsheet. You will need to know how to use this file to calculate the life-cycle cost of your system.

Step 1: Write the start time on the exercise log of your timecard.

Step 2: Click on the EXCEL icon and Open EXCEL file LCC located in the following path on the moderator station: Network Neighborhood\Mgdsl nt server\Users\JMeredith. Please save this file as "LCC-(your initials)."

Step 3: Please enter the data including team name, date, and number of members. Here is a list of parts and labor times that have been used to build a system. Please complete the spreadsheet.

The data to be used for the exercise are as follows:

- Number of team members = 3
- Conceptual Design Labor = 25 minutes
- Detail Design Labor = 45 minutes
- Manufacturing Labor = 15 minutes
- Testing Labor = 10 minutes
- Moving Parts = 9
- Materials
    - 5/8 x 1 ¼ inch standard brick = 1
    - 3/8 x 5/8 inch standard brick = 1
    - Motor = 1
    - Gears = 2
    - 4 Wheels (Tires)
    - Plates with holes = 4
    - Axles = 2
    - 5 inch Beams = 2
    - 1 ¼ inch Beams = 2
    - Bushings = 3 (Miscellaneous)

Parts that you use that are not on the life-cycle cost calculation template have no cost but are counted as unique items (e.g., bushings).

Step 4: Enter the number of unique parts. The correct answer is 10.

Step 5: Print out the spreadsheet and compare it to the following chart.

Step 6: Compare your answer with the correct answer for this tutorial which is $726.00. If you don't get this answer, please recheck your input. The number of total parts is equal to nineteen. The number of unique parts is equal to ten.

Step 7: When you are complete, enter the stop time on the exercise log of your time card.

Step 8: Calculate the total time of your exercise and write it on the time card.

Number of Team Members: __3___

Item Number	Cost Category	Units	Quantity	Unit Price	Amount
Design Cost					
1	Conceptual Design Labor	Minutes	25	$1.00	$75.00
2	Detail Design Labor	Minutes	45	$1.00	$135.00
3	Groupware Cost	Each Member	3	$20.00	$60.00
4	AutoCAD Cost	NA	NA	$50.00	$50.00
Manufacturing Cost					
5	Manufacturing Labor	Minutes	15	$1.00	$45.00
6	Total Material Cost From Bill of Material Form	$$	NA	NA	$260.00
Testing Cost					
7	Testing Labor	Minutes	10	$1.00	$30.00
Maintenance					
8	Moving Parts	Each	9	$5.00	$45.00
9	Spare Parts Cost From Bill of Material Form	NA	NA	NA	$26.00
Total Life-Cycle Cost					$726.00

Item[2]	Dimension	Studs	Available	Used	Unit Cost	Cost
Bricks	5/8 x 2 1/2	16	3		16.00	
	5/8 x 2	12	4		12.00	
	5/8 x 1 1/4	8	127	1	8.00	$8.00
	5/8 x 1	6	34		6.00	
	5/8 x 5/8	4	78		4.00	
	3/8 x 2 1/2	8	22		8.00	
	3/8 x 2	6	34		6.00	
	3/8 x 1 1/4	4	64		4.00	
	3/8 x 1	3	32		3.00	
	3/8 x 5/8	2	82	1	2.00	$2.00
	3/8 x 3/8	1	86		1.00	
Slopes	15/16 x 1 1/4	4	19		4.00	
	15/16 x 5/8	2	4		2.00	
Motor	4.5 Volt	NA	1	1	100.00	$100.00
Gears	Various	NA	25	2	25.00	$50.00
Pulleys/Wheels	Various	NA	7	4	5.00	$20.00
Plates	3 1/8 x 6 1/4	200	2		200.00	
	2 1/2 x 5	128	1		128.00	
	2 x 5	96	1		96.00	
	2 x 3 1/8	60	2		60.00	
	1 1/4 x 2 1/2	32	2		32.00	
Plates w/Holes	Various	Various	15	4	5.00	$20.00
Axles	Various	NA	10	2	10.00	$20.00
Beams	5	16	2	2	16.00	$32.00
	3 3/4	12	2		12.00	
	2 1/2	8	2		8.00	
Beams	2	6	2		6.00	
	1 1/4	4	8	2	4.00	$8.00
	5/8	2	12		2.00	

[2] Any pieces used not on this list are free.

Rubber Bands	Various	NA	1		5.00	
Tape	1/2	NA	1		5.00	
Cardboard	4 x 7	NA	1		10.00	
Battery		NA	1		100.00	
Miscellaneous	Various	NA	NA	3	0.00	
			TOTAL PARTS	19	**TOTAL MATERIAL COST**	$260.00
			MOVING PARTS	9	**SPARE PARTS COST (10% of Total Cost)**	$26.00
			UNIQUE PARTS	10		

D.3. Detail Design

D.3.1. Detail Design Functional Goals

D.3.1.1. Design Goals

A design organization is often measured on their ability to release drawings in a timely manner. Your goal is to try to minimize the amount of time that it takes to complete detail design and issue manufacturing instructions.

D.3.1.2. Manufacturing Goals

A manufacturing organization usually prefers large quantities of standard parts to fabricate. Your goal is to try to influence the design to use a minimum number of unique parts.

D.3.1.3. Support Goals

A support organization is often responsible for life-cycle cost. Your job on the team is to influence the design to minimize life-cycle cost. You should also take the lead in calculating life-cycle cost.

D.3.2. Final Design Review Form

FINAL DESIGN REVIEW FORM

Team Name: ___________________ Function: ____________________ Date:_____________

SA strongly agree	A agree	U undecided	D disagree	SD strongly disagree

1. There is no doubt that the detailed design that we have developed will result in a system that meets its performance requirements.

SA **A** **U** **D** **SD**

2. No one on our team has emerged as the leader of the team.

SA **A** **U** **D** **SD**

3. The final detail design is a team effort representing contributions from all team members.

SA **A** **U** **D** **SD**

4. Each functional member of the team achieved his or her functional goals.

SA **A** **U** **D** **SD**

5. Life-cycle cost goals influenced the detail design process.

SA **A** **U** **D** **SD**

6. Manufacturing goals influenced the detail design process.

SA **A** **U** **D** **SD**

7. The Design functional goals influenced the detail design process.

SA **A** **U** **D** **SD**

8. I achieved my functional role’s objective.

SA **A** **U** **D** **SD**

9. The interaction among our team members was outstanding with little conflict.

SA **A** **U** **D** **SD**

D.4. Manufacturing

D.4.1. Design Errors and Defects Form

DESIGN ERRORS AND DEFECTS FORM

Team Name: ___________________ Date:______________

Please list below all design errors and defects in the manufacturing instruction package that were identified with the researcher during the Test Readiness Review.

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____
8. ____
9. ____
10. ____

D.4.2. Test Readiness Review Form

TEST READINESS REVIEW FORM

Team Name: __________________ Function: ___________________ Date:_____________

SA	A	U	D	SD
strongly agree	**agree**	**undecided**	**disagree**	**strongly disagree**

1. There is no doubt that the system that we have built will meet its performance requirements.

SA **A** **U** **D** **SD**

2. In retrospect, our team designed as good a system as we were capable of.

SA **A** **U** **D** **SD**

3. Each member of the team made a significant contribution to the final system.

SA **A** **U** **D** **SD**

D.5. Testing

D.5.1 Life Cycle Cost Form

LIFE-CYCLE COST FORM

Team Name: ___________________ Function: ____________________ Date:_____________

Please calculate the life-cycle cost of your design using the following relationships: * Note that labor is calculated based on the number of team members times the time required to complete the phase of the task.

Number of Team Members: _____

Item Number	Cost Category	Units	Quantity	Unit Price	Amount
Design Cost					
1	Conceptual Design Labor	Minutes		$1.00	
2	Detail Design Labor	Minutes		$1.00	
3	Groupware Cost	Each Member		$20.00	
4	AutoCAD Cost	NA	NA	$50.00	
Manufacturing Cost					
5	Manufacturing Labor	Minutes		$1.00	
6	Total Material Cost From Bill of Material Form	$$	NA	NA	
Testing Cost					
7	Testing Labor	Minutes		$1.00	
Maintenance					
8	Moving Parts	Each		$5.00	
9	Spare Parts Cost From Bill of Material Form	NA	NA	NA	
Total Life-Cycle Cost					

Item[3]	Dimension	Studs	Available	Used	Unit Cost	Cost
Bricks	5/8 x 2 1/2	16	3		16.00	
	5/8 x 2	12	4		12.00	
	5/8 x 1 1/4	8	127		8.00	
	5/8 x 1	6	34		6.00	
	5/8 x 5/8	4	78		4.00	
	5/16 x 2 1/2	8	22		8.00	
	5/16 x 2	6	34		6.00	
	5/16 x 1 1/4	4	64		4.00	
	5/16 x 1	3	32		3.00	
	5/16 x 5/8	2	82		2.00	
	5/16 x 5/16	1	86		1.00	
Slopes	15/16 x 1 1/4	4	19		4.00	
	15/16 x 5/8	2	4		2.00	
Motor	4.5 Volt	NA	1		100.00	
Gears	Various	NA	25		25.00	
Pulleys/Wheels	Various	NA	7		5.00	
Plates	3 1/8 x 6 1/4	200	2		200.00	
	2 1/2 x 5	128	1		128.00	
	2 x 5	96	1		96.00	
	2 x 3 1/8	60	2		60.00	
	1 1/4 x 2 1/2	32	2		32.00	
Plates w/Holes	Various	Various	15		5.00	
Axles	Various	NA	10		10.00	
Beams	5	16	2		16.00	
	3 3/4	12	2		12.00	
	2 1/2	8	2		8.00	
Beams	2	6	2		6.00	
	1 1/4	4	8		4.00	
	5/8	2	12		2.00	
Rubber Bands	Various	NA	1		5.00	

[3] Any pieces used not on this list are free.

Tape	1/2	NA	1		5.00	
Cardboard	4 x 7	NA	1		10.00	
Battery		NA	1		100.00	
Miscellaneous	Various	NA	NA		0.00	
			TOTAL PARTS		**TOTAL MATERIAL COST**	
			MOVING PARTS		**SPARE PARTS COST (10% of Total Cost)**	
			UNIQUE PARTS			

D.5.2. Final Project Review Form

FINAL PROJECT REVIEW FORM

Team Name: ___________________ Date:______________

If we knew in the beginning what we know now, we would have:

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____
8. ____
9. ____
10. ____

D.5.3. Individual Post-Experiment Questionnaire

INDIVIDUAL POST-EXPERIMENT QUESTIONNAIRE

Team Name: ___________________ Function: ____________________ Date:______________

SA	A	U	D	SD
strongly agree	**agree**	**undecided**	**disagree**	**strongly disagree**

1. I think that we designed the best system that we could have.

SA **A** **U** **D** **SD**

2. I was satisfied with the process that my team used to create ideas.

SA **A** **U** **D** **SD**

3. I was satisfied with the process that we used to develop the detail design.

SA **A** **U** **D** **SD**

4. Everyone on the team was given a chance to make a contribution.

SA **A** **U** **D** **SD**

5. Everyone on the team contributed to the final product.

SA **A** **U** **D** **SD**

6. There was little discussion conflict on our team.

SA **A** **U** **D** **SD**

7. I agreed with the final system that we developed.

SA **A** **U** **D** **SD**

8. When I'm in a team situation I'm usually the leader.

SA **A** **U** **D** **SD**

9. When I'm in a meeting I'm usually very outspoken.

SA **A** **U** **D** **SD**

10. I know my team members very well.

SA **A** **U** **D** **SD**

11. Using AutoCAD is an important part of engineering design.

SA **A** **U** **D** **SD**

12. I was extremely satisfied with the process that was used to develop a concept, perform a detail design, manufacture, and test a system.

SA **A** **U** **D** **SD**

13. Please describe the overall strategy that your team used to solve the design problem.

D.5.4. Team Post-Experiment Questionnaire

TEAM POST-EXPERIMENT QUESTIONNAIRE

Team Name: ___________________ Date:______________

SA	A	U	D	SD
strongly agree	**agree**	**undecided**	**disagree**	**strongly disagree**

1. We think that we designed the best system that we could have.

SA **A** **U** **D** **SD**

2. We were satisfied with the process that our team used to create ideas.

SA **A** **U** **D** **SD**

3. We were satisfied with the process that we used to develop the detail design.

SA **A** **U** **D** **SD**

4. Everyone on the team was given a chance to make a contribution.

SA **A** **U** **D** **SD**

5. Everyone on the team contributed to the final product.

SA **A** **U** **D** **SD**

6. There was little discussion conflict on our team.

SA **A** **U** **D** **SD**

7. We all agreed with the final system that we developed.

SA **A** **U** **D** **SD**

D.6. Other Forms

D.6.1. Researcher's Log

Team Name: __________________ Date:_____________

Start time of Experiment: _____________

CONCEPTUAL DESIGN

Time: ________

1. How many ideas were considered? _____ How many comments were generated? ________
2. Functional effectiveness:

Design:	Process Time:	_____	
Manufacturing:	Cube Size:	_____	(Complete later)
Support:	Moving Parts:	_____	(Complete later)

3. Amount of consideration of manufacturing and support goals in sequential process

Manufacturing	None	Some	Much	Time: ______
Support	None	Some	Much	Time: ______

DETAIL DESIGN

Time: _________

1. Functional effectiveness:

Design:	Process Time:	_____	
Manufacturing:	Unique Parts:	_____	(Complete later)
Support:	Life-Cycle Cost:	_____	(Complete later)

2 Amount of consideration of manufacturing and support goals in sequential process

Manufacturing	None	Some	Much	Time: ______
Support	None	Some	Much	Time: ______

MANUFACTURING

Time: _______

1. Life-Cycle Cost: _____

TESTING

Time: _________

		Test	1	2	3	4	5	6
1.	Range and Accuracy:		_____	_____	_____	_____	_____	_____
	500	Ball crossed finish line						
	400	Ball crossed extended line						
	200	Ball crossed hurdle line						
	0	Ball didn't cross hurdle line						

Average Range and Accuracy: ___________

2. Producability: __________ ___________

500	Assembly Time < 5 minutes
400	Assembly Time < 10 minutes
300	Assembly Time < 15 minutes
200	Assembly Time < 20 minutes
100	Assembly Time < 25 minutes
0	Assembly Time > 25 minutes

3. Size __________________ ___________

500	Size <50 cubic inches
400	50 < Size < 100 cubic inches
300	100 < Size < 150 cubic inches
200	150 < Size < 200 cubic inches
100	Size > 200 cubic inches

3. System Effectiveness: ___________

4. Life-Cycle Cost: ___________

5. COST EFFECTIVENESS = System Effectiveness / Life-Cycle Cost = ___________

6. PROCESS TIME: _____

7. PROCESS COST: _____

8. SYMLOG SCORES:

Design 1: __________ Manufacturing 1: __________ Support 1: __________
Design 2: __________ Manufacturing 2: __________ Support 2: __________

Group: __________

Overall Stop Time of Experiment: ________
Total Experiment Time: _________

Abnormalities:

Observations:

D.6.2. SYMLOG Adjective Rating Scale

Team Name: ___________________ Date:______________

Role: Design _______ Manufacturing _________ Support __________

		never	rarely	sometimes	often	always
U	active, dominant, talks a lot	0	6	12	18	24
UP	extroverted, outgoing, positive	0	3	6	9	12
UPF	a purposeful democratic task leader	0	2	4	6	8
UF	an assertive business-like manager	0	3	6	9	12
UNF	authoritarian, controlling, disapproving	0	2	4	6	8
UN	domineering, tough-minded, powerful	0	3	6	9	12
UNB	provocative, egocentric, shows off	0	2	4	6	8
UB	jokes around, expressive, dramatic	0	3	6	9	12
UPB	entertaining, sociable, smiling, warm	0	2	4	6	8
P	friendly, equalitarian	0	6	12	18	24
PF	works cooperatively with others	0	3	6	9	12
F	analytical, task-oriented, problem-solving	0	6	12	18	24
NF	legalistic, has to be right	0	3	6	9	12
N	unfriendly, negativistic	0	6	12	18	24
NB	irritable, cynical, won't cooperate	0	3	6	9	12
B	shows feelings and emotions	0	6	12	18	24
PB	affectionate, likable, fun to be with	0	3	6	9	12
DP	looks up to others, appreciative, trustful	0	3	6	9	12
DPF	gentle, willing to accept responsibility	0	2	4	6	8
DF	obedient, works submissively	0	3	6	9	12
DNF	self-punishing, works too hard	0	2	4	6	8
DN	depressed, sad, resentful	0	3	6	9	12
DNB	alienated, quits, withdraws	0	2	4	6	8
DB	afraid to try, doubts own ability	0	3	6	9	12
DPB	quietly happy just to be with others	0	2	4	6	8
D	passive, introverted says little	0	6	12	18	24

D.6.3. SYMLOG Key for Tabulation of Directional Profiles

	B	**F**	**N**	**P**	**D**	**U**
U						
UP						
UPF						
UF						
UNF						
UN						
UNB						
UB						
UPB						
P						
PF						
F						
NF						
N						
NB						
B						
PB						
DP						
DPF						
DF						
DNF						
DN						
DNB						
DB						
DPB						
D						
TOTAL						
U						
D						
P						
N						
F						
B						

D.6.4. SYMLOG Directional Profile Form

	D1	**D2**	**M1**	**M2**	**S1**	**S2**	**GROUP**
U							
UP							
UPF							
UF							
UNF							
UN							
UNB							
UB							
UPB							
P							
PF							
F							
NF							
N							
NB							
B							
PB							
DP							
DPF							
DF							
DNF							
DN							
DNB							
DB							
DPB							
D							
TOTAL							

U															
D															
P															
N															
F															
B															

D.6.5. Videotape Log Form

TEAM NAME	DATE	TAPE NUMBER(S)

D.6.6. LEGO Bill of Material

LEGO BILL OF MATERIAL

OBJECT FILE NAMES

STANDARD PIECES - Doubles (Width = 5/8, Height = 3/8)

Front	Top	End	Length	Quantity Available
s_8s	t_16s	s_2s	2 1/2	3
s_6s	t_12s	s_2s	7/8	4
s_4s	t_8s	s_2s	1 1/4	127
s_3s	t_6s	s_2s	15/16	34
s_2s	t_4s	s_2s	5/8	78
s_1s	t_2s	s_2s	5/16	82

STANDARD PIECES - Singles (Width = 5/16, Height = 3/8)

Front	Top	End	Length	Quantity Available
s_8s	t_8s	s_1s	2 1/2	22
s_6s	t_6s	s_1s	1 7/8	34
s_4s	t_4s	s_1s	1 1/4	64
s_3s	t_3s	s_1s	15/16	32
s_2s	t_2s	s_1s	5/8	82
s_1s	t_1s	s_1s	5/16	86

STANDARD PIECES - Plates

Front	Top	End	Size	Quantity Available
20p	200p	10p	6 1/4 x 3 1/8 x 3/8	2
16p	128p	8p	5 x 2 1/2 x 3/8	1
16pt	96pt	6pt	5 x 1 7/8 x 1/8	1
10pt	60pt	6pt	3 1/8 x 1 7/8 x 1/8	2
8pt	32pt	4pt	2 ½ x 1 1/4 x 1/8	2

STANDARD PIECES - Slopes

			Size	Quantity Available
SLF	4SLT	4SLE	1 1/4 x 15/16 x 3/8	19
SLF	2SLT	2SLE	5/8 x 15/16 x 3/8	4

TECHNICAL PIECES - Axles (Diameter = 3/16)

			Length	Quantity Available
12a	12a	a	3 3/4	2
10a	10a	a	3 1/8	2
8a	8a	a	2 1/2	2
6a	6a	a	1 7/8	4
4a	4a	a	1 1/4	6

TECHNICAL PIECES - Beams (Width = 5/16, Height = 3/8)

			Length	Quantity Available
16b	16b	b	5	2
12b	12b	b	3 3/4	2
8b	8b	b	2 1/2	2
6b	6b	b	1 7/8	2
4b	4b	b	1 1/4	8
2b	2b	b	5/8	12

TECHNICAL PIECES - Doubles Plates (Width = 5/8, Height = 1/8)

			Size	Quantity Available
tp_8t	tp_16t	tp_2t	2 ½	4
tp_4t	tp_8t	tp_2t	1 1/4	6
tp_3t	tp_6t	tp_2t	15/16	4

TECHNICAL PIECES - Singles Plates (Width = 5/16, Height = 1/8)

			Size	Quantity Available
tp_8t	tp_8t	tp_1t	2 1/2	4
tp_6t	tp_6t	tp_1t	1 7/8	4
tp_4t	tp_4t	tp_1t	1 1/4	4
tp_3t	tp_3t	tp_1t	15/16	4

TECHNICAL PIECES - Gears

			Diameter	Quantity Available
40gs	40g	40gs	1 5/8	2
24gs	24g	24gs	1	4
16gs	16g	16gs	3/4	2
8gs	8g	8gs	3/8	5

TECHNICAL PIECES - Bevel Gears

			Diameter	Quantity Available
24bgs	24bg	24bgs	1	2
16bgs	16bg	16bgs	5/8	6

TECHNICAL PIECES - Worm Gears

			Length	Quantity Available
12wgf	12wgt	12wge	1 1/4	2
10wg	10wg	10wge	5/8	2

TECHNICAL PIECES - Pulleys

			Diameter	Quantity Available
PUF	PU	PU	1 1/2	1
PU1F	PU1	PU1	1	6

TECHNICAL PIECES - Miscellaneous

			Name	Quantity Available
d	dt	d	Differential	1
cp	cp	cpe	Connector Peg	16
bu	bu	bue	Bushings	10
abf	abt	abe	Axle Bushings	10
xef	xef	xee	Axle Extender	1
mf	mt	me	Motor (4.5 Volt)	1
bp	bp	bpe	Battery Pack	1
t1f	t1	t1	Tires	4

Not modeled in CAD:

String (30”)	1
Battery / Motor Connector (29”)	1
Pulleys/Bands (Various Sizes)	19

D.6.7. Completed Data Package Checklist

DATA PACKAGE CHECKLIST

- Consent Forms
- Demographic Forms
- Groupware Printout or Idea Listing with Comments
- Design Concept Form
- System Concept Form
- Preliminary Design Review
- Final Design Review
- Test Readiness Review
- Design Errors and Defects
- Final Project Review
- Individual Post-Experiment Questionnaire
- Team Post-Experiment Questionnaire
- AutoCAD Drawing
- Time Card and Exercise Log
- Life-Cycle Cost Calculation
- Researcher’s Log
- Videotapes
- Photographs

D.6.8. Building Construction Evaluation Form

BUILDING CONSTRUCTION STUDENT EVALUATION FORM

1. Do you think that this exercise is relevant to learning about the design/construction process?

    Yes ______ No ______

2. Do you think that it should be included as an exercise in future building construction classes?

    Yes ______ No ______

3. If your answer is "Yes", then which class? __________________

4. List some of the things that you learned from this exercise:

5. How could the exercise be improved to make it a better learning experience or more relevant to building construction?

6. Please circle your current class:

BC1224 BC2024 BC4014 BC4444 BC5124

Appendix E - Experimental Data

E.1. Sequential Engineering With Computer Support

Sequential Engineering With Computer Support										
	SMALL					LARGE				
TEAMS	1	2	3	4	5	1	2	3	4	5
TEAM NAME	I	L	Q	AC	AI	D	R	W	AD	AM
Concept Design										
Time (CD)	53	35	42	49	50	57	56	50	60	55
Cost (CD)	159	105	126	147	150	342	336	300	360	330
Total Ideas	7	18	8	12	20	11	24	28	35	35
Final Ideas	7	12	8	12	20	10	24	28	35	35
Ideas/Person	1.33	1.33	1	1.33	1.33	.5	1.17	.83	1	.67
Comments	25	31	24	26	33	32	50	50	52	54
Preliminary Design										
Q1	2.3	1.6	1.3	1.6	1.3	2.8	1.8	2.3	1.5	2.3
Q2	2.3	1.6	2.6	3	2.6	3.8	4	2.1	2.6	3.3
Q3	2.6	1.6	1.3	1	1.6	2.5	2	1.5	2.1	3
Q4	2.3	1.3	2	2	2.3	2.8	2.1	2	2.3	2.3
Q5	2	1.6	2	1	1.3	1.3	1.6	1.3	1.5	1.8
Q6	1.6	1.3	2	1.3	1.3	1.3	2	1.6	1.5	2.6
Q7	1.6	2.3	1.6	1.6	1.6	2	1.3	1.3	1.6	1.6
Q8	3.6	3.3	2.6	2	2.3	3	2.3	2	2.3	2.3
Q9	3.6	3.3	3	2	2.6	3.5	2.6	2	2.3	2.5
Q10	3.3	2.6	2.6	2	3	2.8	2.8	2.5	2.3	2.1
Q11	3	2.6	2.3	2.3	1.6	1.6	2.6	1.8	2	1.8
Q12	3	2.6	2.6	2	2.3	2.3	2.5	2	2.1	2.3
Detail Design										
Time (DD)	116	50	64	45	26	76	41	47	50	55
Cost (DD)	348	150	192	135	78	456	246	282	300	330
Tutorials										
AutoCAD	19	14	6	4	8	13	7	9	10	6
Assembly	16	8	11	6	9	12	4	9	5	8
LCC	12	11	9	7	6	15	7	7	7	3
Final Design										
Q1	1.3	2	1	1	1	1.5	1.5	1.3	1.6	1.3
Q2	2	2	3	2	2.3	2.6	3.6	2.3	3	2.3
Q3	1.3	1.3	2	1.3	1	1.5	1.6	1.6	2.1	2
Q4	1.6	1.6	1.6	1	1	1.3	1.6	1.5	1.6	2.3
Q5	4	1.6	2	1.6	2	1	1.8	1.6	2	2.1
Q6	3.3	1.6	2	1.6	2	1.3	1.8	1.6	1.8	1.6
Q7	3	1.6	2	1.6	2.3	2.5	1.3	1.6	2.1	2.1
Q8	3	1.6	2	1.3	1	1.5	1.3	1.6	1.6	1.8
Q9	1.3	1.3	1.3	1.3	1.3	1.3	1.5	1.1	1.8	1.6

TEAMS	1	2	3	4	5	1	2	3	4	5
Manufacturing										
Time (MF)	7	13	6	2	13	8	4	3	10	14
Cost (MF)	21	39	18	6	39	48	24	18	60	84
Design Errors	2	0	1	0	1	4	1	2	1	1
Manufacturing Errors	1	0	1	1	0	0	0	0	0	0
Test Readiness										
Q1	1.6	1.3	1	1.3	1	1.6	1.1	1.5	1.3	1.8
Q2	2	2	2.3	1	3.6	3	2.1	2	2.5	2.1
Q3	2	1	1.6	1	1.3	1.3	1.6	1.5	1.6	2.1
Testing										
Time (TE)	5	3	2	6	8	12	2	1	4	2
Cost (TE)	15	9	6	18	24	72	12	6	24	12
Attempts	6	6	6	6	3	6	6	3	3	3
Successes	4	4	3	4	2	5	3	2	2	1
Ind. Questionnaire										
Q1	2.3	1.6	2.3	1.3	4	2.3	2.5	2.1	2.8	3.1
Q2	2	1.3	2	1	2.3	2.1	3	2	2.3	2.1
Q3	2.6	1.3	1.6	1	1.6	2.5	3	2	2.1	2.5
Q4	1	1	1.6	1	1.3	1.3	1.1	1.3	1.5	1.6
Q5	1	1	1.6	1	1.3	1.3	1.3	1.3	1.6	2.3
Q6	1.6	1	1.6	1	2.6	1.8	1.8	1.6	1.8	1.8
Q7	1	1	2	1	2.6	1.5	1.5	1.6	1.8	2.1
Q8	3	3	3.3	3	2	3	3	3.6	2.8	2.5
Q9	3	3	3	3	2.6	2.5	2.6	3.5	2.5	2.3
Q10	2.6	3	2.6	2.6	3.3	3.8	4	3.5	4.1	3.5
Q11	2.3	1.6	2.3	2	2	3.5	1.8	2	3.1	2
Q12	2	2	2	1	2	2.6	3	2.3	2.6	2.1
Team Questionnaire										
Q1	3	1	1	2	5	2	2	2	2	3
Q2	2	2	1	1	4	3	4	2	2	2
Q3	2	2	2	1	2	4	2	1	3	3
Q4	1	1	1	1	1	1	2	1	1	2
Q5	1	1	1	1	1	1	2	1	1	2
Q6	1	1	1	1	1	1	2	1	1	2
Q7	1	1	1	1	1	2	2	1	2	2
SYMLOG										
U	57	51	40	41	57	31	36	45	40	48
D	18	16	28	16	18	32	26	17	22	21
U/D	39U	35U	12U	25U	39U	1D	9U	27U	19U	27U
P	64	56	49	52	57	49	50	56	48	53
N	20	15	10	3	13	11	6	3	8	12
P/N	44P	41P	39P	44P	44P	38P	43P	54P	40P	41P
F	60	49	44	45	56	45	43	45	45	46
B	30	31	27	27	33	28	27	29	25	30
F/B	30F	18F	17F	19F	23F	17F	16F	17F	20F	16F

TEAMS	1	2	3	4	5	1	2	3	4	5
Functional Effectiveness										
Design Time	169	85	106	94	76	133	97	97	110	110
Manufact. Cube Size	135	47	88	54	3	6	35	60	116	188
Manufact. Unique Parts	9	10	13	11	4	6	11	7	11	13
Support Moving Parts	5	1	1	3	1	2	1	1	1	3
Labor	543	303	342	306	291	918	618	606	744	756
Material	528	277	360	334	180	95	72	240	267	383
Support LCC	1258	722	853	798	604	1202	872	1045	1212	1362
Effectiveness										
Range/Accuracy	500	500	500	500	400	500	500	333	333	300
Producability	400	300	400	500	300	400	500	500	400	300
Size	300	500	400	400	500	500	500	400	300	200
System Effectiveness	1240	1361	1300	1521	1200	1492	1500	1233	1033	800
Cost Effectiveness	.99	1.88	1.52	1.91	1.99	1.24	1.72	1.18	.85	.59
Process Time	181	101	114	102	97	153	103	101	124	126
Process Cost	653	413	452	416	401	1088	788	776	914	926
Elapsed Time (HR:M)	3:55	2:45	2:55	2:24	2:30	3:22	2:26	2:31	2:54	2:51
Elapsed Time (HR)	3.92	2.75	2.92	2.40	2.50	3.37	2.43	2.52	2.90	2.85
Derived Measures										
Dom. Difference	17	43	107	3	28	124	101	76	102	134
Dom. Dispersion	6.42	17.35	43.48	1.22	9.91	41.67	32.69	23.21	39.82	41.64
Concept/Detail Design	.46	.70	.65	1.09	1.92	.75	1.37	1.06	1.20	1.00

E.2. Sequential Engineering Without Computer Support

Sequential Engineering Without Computer Support										
	SMALL					LARGE				
TEAMS	1	2	3	4	5	1	2	3	4	5
TEAM NAME	H	M	S	AH	AK	E	Y	AB	AE	AN
Concept Design										
Time (CD)	32	41	26	39	30	47	31	45	37	38
Cost (CD)	96	123	78	117	90	282	186	270	222	228
Total Ideas	6	5	5	6	6	9	14	13	13	10
Final Ideas	3	6	6	6	6	9	14	13	13	10
Ideas/Person	.67	1	1.33	.67	1.33	1	.83	1	1.16	.83
Comments	43					58				
Preliminary Design										
Q1	1.6	1	2	2.3	2	2.3	1.8	2.3	1.1	1.3
Q2	2.3	3.6	2	2.6	2.6	2.5	2.1	3.5	2.6	2.5
Q3	2.6	1.6	1.6	2.6	2.3	1.8	1.5	1.5	1.3	1.5
Q4	2	1.6	1.6	3	2.3	2.5	1.8	2	1.6	2.5
Q5	1.3	1	1.6	2	1.3	2	1.3	1.8	1.1	1.3
Q6	1.3	1.6	2	2.6	2	2.3	1.1	1.5	1.3	1.5
Q7										
Q8										
Q9										
Q10										
Q11										
Q12										
Detail Design										
Time (DD)	76	32	61	54	82	74	43	32	48	39
Cost (DD)	228	96	183	162	246	444	258	192	288	234
Tutorials										
AutoCAD	24	12	8	14	7	19	9	4	7	10
Assembly	19	12	10	13	12	9	7	7	4	6
LCC	14	12	10	13	8	4	6	5	10	9
Final Design										
Q1	1.3	1.3	1.6	1.3	1.6	1.6	1.3	2.1	1.1	1.1
Q2	2.3	3.3	2.3	3	1.3	2.6	2	3.5	2.1	2
Q3	1.3	1.3	1.6	1.6	1	2.3	1.1	1.8	1.3	1.3
Q4	1.6	2	1.6	2.6	1.6	2.6	1.5	1.8	1.3	1.8
Q5	2.3	3	1.6	2.3	2	2.1	1.6	1.8	1.1	2.6
Q6	2	1	1.6	1.6	2	1.8	1.5	1.3	1.3	2.1
Q7	2	1.3	1.6	1.6	1.6	2.3	1.3	1.5	1.8	1.6
Q8	2	1.6	1.6	2	2	2.6	1.3	1.5	1.3	1.6
Q9	1	1.6	1.6	2.6	1.3	2	1.1	1.8	1.1	1.5

TEAMS	1	2	3	4	5	1	2	3	4	5
Manufacturing										
Time (MF)	10	9	6	7	5	10	6	6	4	6
Cost (MF)	30	27	18	21	15	60	36	36	24	36
Design Errors	3	0	2	1	1	5	0	1	0	0
Manufacturing Errors	0	0	1	0	0	0	0	0	0	1
Test Readiness										
Q1	1.6	1.3	1.6	1.3	2	2.3	1.3	2	1.1	1.5
Q2	1.3	2.6	1.6	2.3	2	2.3	1.3	1.8	1	1.5
Q3	1	1.6	1.6	1.6	1	2.1	1	1.5	1	1.3
Testing										
Time (TE)	2	4	6	4	2	4	6	4	3	2
Cost (TE)	6	12	18	12	6	24	36	24	18	12
Attempts	3	6	6	6	6	3	6	6	6	6
Successes	1	3	6	3	3	0	3	3	6	3
Ind. Questionnaire										
Q1	3	2	1.6	3.6	1	3	3	1.6	1.1	2
Q2	1.6	2.3	1.6	4	1	2	1.1	1.3	1	1.5
Q3	1.6	2	1.6	3.3	1.3	3	2.1	2	1	1.8
Q4	1	1	1.6	2.6	1	1.8	1.3	1.5	1	1.5
Q5	1	1.6	1.6	2	1	2.1	1.1	1.3	1	1.5
Q6	1	2.3	1.6	3.6	1.3	2	1	1.8	1	2.1
Q7	1.6	1	1.6	1.6	1.3	1.8	1.3	1.5	1	1.5
Q8	3	2.3	2.6	2	2.6	3.1	3.1	2.5	2.1	2.8
Q9	1.3	2.6	3	2	3	2.P	2.6	2.3	2	2.8
Q10	2.6	2.6	3	3	3.3	4.5	3.5	3.3	2	3.3
Q11	3	1.6	2.3	2.3	2	3	2	2.6	2.1	2
Q12	2	1.3	1.6	3	1.3	2.8	1.8	1.8	1.3	2.1
Team Questionnaire										
Q1	3	2	1	4	1	2	3	2	1	2
Q2	1	1	1	4	1	2	1	1	1	2
Q3	2	1	1	2	1	4	2	2	1	1
Q4	1	1	1	2	1	1	1	1	1	1
Q5	1	1	1	2	1	1	1	1	1	1
Q6	1	2	1	4	1	1	1	2	1	2
Q7	1	1	1	2	1	1	1	2	1	1
SYMLOG										
U	50	47	33	59	41	44	50	47	37	48
D	23	22	29	12	25	17	22	14	20	21
U/D	27U	24U	3U	47U	17U	26U	28U	33U	17U	27U
P	47	45	42	44	51	56	54	54	51	55
N	11	25	5	35	9	4	9	7	0	9
P/N	36P	21P	38P	9P	42P	51P	45P	46P	51P	46P
F	63	54	40	58	45	49	48	46	43	55
B	30	31	23	34	27	29	27	28	20	28
F/B	33F	24F	17F	24F	17F	20F	21F	18F	23F	26F

TEAMS	1	2	3	4	5	1	2	3	4	5
Functional Effectiveness										
Design Time	132	73	87	93	112	121	74	77	85	77
Manufact. Cube Size	17	54	25	52	20	112	9	0	37	75
Manufact. Unique Parts	9	7	13	12	14	8	8	2	11	10
Support Moving Parts	1	1	3	1	2	1	1	1	2	1
Labor	360	258	297	312	357	810	516	522	552	510
Material	174	461	425	160	225	431	62	10	312	223
Support LCC	606	820	829	543	664	1339	679	588	955	810
Effectiveness										
Range/Accuracy	166	500	500	500	500	333	500	500	500	500
Producability	400	400	400	400	500	400	400	400	500	400
Size	500	400	500	400	500	300	500	500	500	400
System Effectiveness	1066	1317	1540	1300	1500	1033	1400	1400	1650	1300
Cost Effectiveness	1.75	1.6	1.85	2.39	2.25	.77	2.06	2.38	1.73	1.60
Process Time	120	86	99	104	119	135	86	87	92	85
Process Cost	410	308	347	362	407	860	566	572	602	560
Elapsed Time (HR:M)	2:58	2:46	2:43	2:47	2:45	3:03	2:12	2:21	2:13	2:18
Elapsed Time (HR)	2.97	2.77	2.72	2.78	2.75	3.05	2.2	2.35	2.22	2.30
Derived Measures										
Dom. Difference	36	85	60	51	91	49	96	93	59	101
Dom. Dispersion	13.37	30.42	21.22	18.98	35.99	16.97	36.41	26.19	19.30	31.10
Concept/Detail Design	.42	1.28	.43	.72	.37	.64	.72	1.41	.77	.97

E.3. Concurrent Engineering With Computer Support

Concurrent Engineering With Computer Support										
	SMALL					LARGE				
TEAMS	1	2	3	4	5	1	2	3	4	5
TEAM NAME	B	K	P	AG	AJ	C	V	X	Z	AF
Concept Design										
Time (CD)	50	25	42	32	46	55	65	47	61	58
Cost (CD)	150	75	126	96	138	330	390	282	366	348
Total Ideas	5	13	18	16	18	23	18	50	30	33
Final Ideas	5	10	18	16	18	23	18	50	30	33
Ideas/Person	.67	2	1.67	1.33	2.3	1.17	1	1.5	.83	1.5
Comments	14	47	50	21	37	44	48	66	50	84
Preliminary Design										
Q1	2.6	1	1.3	2.3	2.3	1.8	1.5	1.1	1.8	2.3
Q2	2.3	1.6	2.6	2.6	2.6	2.3	2.3	2.1	3	2.5
Q3	2	1.3	1.3	1.6	1	2	1.5	1.3	2.3	2.1
Q4	3	2	1	2.3	2.3	2.8	2.5	1.8	2.3	2.6
Q5	2	1	1	2	1	1.5	1.5	1.1	1.5	1.8
Q6	2	1	1.3	2	1.3	1.3	1.6	1.3	1.6	2
Q7	2	1	1.3	2	1.3	1.6	1.6	1.6	1.5	1.5
Q8	3	3.3	3.6	3	2.6	2.6	2.3	2.5	2	2.5
Q9	3.6	3.3	4	3	3	2.6	2.3	2.3	1.8	2.1
Q10	3	3.6	3.6	2.6	2.3	3	1.8	3.1	1.8	2.8
Q11	3.3	2.6	3.3	2.6	2.3	1.8	2.1	1.8	1.8	1.8
Q12	3.3	3	3.3	2.6	2	2	2.1	2.1	1.8	2.5
Detail Design										
Time (DD)	68	31	38	18	43	45	42	31	57	29
Cost (DD)	204	93	114	54	129	270	252	186	342	174
Tutorials										
AutoCAD	21	17	16	7	9	28	12	6	8	4
Assembly	15	8	6	7	12	17	9	4	11	8
LCC	13	8	6	9	9	6	13	10	6	6
Final Design										
Q1	2.3	1	1.6	1.3	1.6	1.8	1	1	1.1	1.3
Q2	2.3	1.6	3.3	2	2.3	1.8	2.1	2.1	2.3	2.6
Q3	2.6	1.3	2	1	1	2	1.3	1	1.6	1.6
Q4	1.3	1	1	1.3	2.3	1.8	2	1.3	1.6	1.8
Q5	1.3	1.3	1.3	3.3	1.3	2	1.5	2.8	1.8	1.5
Q6	2	1.6	1.6	1.6	1.3	2.3	2	2	1.6	2.3
Q7	2	1.3	1.6	1.6	1.6	2.3	2	2	1.6	2.3
Q8	1.3	1	1	2	1.3	1.3	1.8	1.6	1.5	1.5
Q9	1.6	1	1.6	1.3	1.3	1.1	1.5	1.3	1.5	1.5

TEAMS	1	2	3	4	5	1	2	3	4	5
Manufacturing										
Time (MF)	6	10	13	5	11	3	4	3	4	10
Cost (MF)	18	30	39	15	33	18	24	18	24	60
Design Errors	1	0	0	0	0	1	0	1	1	2
Manufacturing Errors	1	0	1	1	0	0	0	0	0	0
Test Readiness										
Q1	2.3	1.6	1.3	1.3	1.6	1.5	1.1	1	1.1	2.3
Q2	1.6	2	1	2	2.3	1.8	1.5	1.1	1.3	3
Q3	1.6	1.3	1.3	1.6	1	1.6	1.5	1	1.5	1.8
Testing										
Time (TE)	8	3	2	3	2	7	3	2	2	4
Cost (TE)	24	9	6	9	6	42	18	12	12	24
Attempts	3	3	6	6	6	6	6	6	6	3
Successes	2	1	3	5	3	3	3	3	3	1
Ind. Questionnaire										
Q1	2.6	2.6	1.3	2.3	3.3	2.5	2.3	2.6	1.5	3.3
Q2	2.6	1.3	1.6	2.6	2	1.6	2	1.1	1.6	2.8
Q3	2	1.3	1.3	2.3	2.3	1.8	1.8	2.3	1.3	2.8
Q4	1.3	1	1.3	1.3	1.3	1.6	1.5	1.1	1.3	1.8
Q5	2	1	1.3	1.3	1.3	1.6	1.6	1.1	1.5	1.8
Q6	1.6	1.3	2	1	1.6	1.5	2.1	1.8	1.3	1.8
Q7	1.6	2	1	1.3	1.3	1.5	1.5	1.1	1.1	2.3
Q8	3	3.6	1.6	3	3	2.6	2.3	2.8	2.6	3
Q9	3.3	3.3	1.6	2.6	2	2.6	2.1	2.5	2.8	3.1
Q10	4.3	4	1.3	1.6	1.6	3.5	4.3	4.1	3.1	4.1
Q11	2.6	2.3	1	3	1.6	2.8	3	2.8	2	2.6
Q12	2.6	2	1.3	2	2.3	2.6	2	2.1	1.8	2.5
Team Questionnaire										
Q1	2	4	1	2	4	2	2	3	1	3
Q2	2	2	1	3	2	1	2	1	1	2
Q3	2	2	1	2	4	1	2	4	2	2
Q4	1	1	1	1	1	1	1	1	1	2
Q5	1	1	1	1	1	1	1	1	1	1
Q6	2	2	2	1	1	1	1	1	1	1
Q7	2	2	1	1	2	1	1	1	1	3
SYMLOG										
U	35	51	53	45	61	-	43	38	46	40
D	19	15	13	12	13	-	25	21	13	16
U/D	16U	36U	41U	33U	48U	-	18U	17U	33U	24U
P	49	59	42	49	62	-	49	51	52	48
N	7	2	28	10	8	-	13	4	6	10
P/N	42P	57P	15P	39P	54P	-	37P	47P	46P	38P
F	51	51	48	45	54	-	47	39	45	42
B	18	31	26	28	32	-	26	28	26	23
F/B	33F	20F	22F	17F	22F	-	20F	11F	20F	19F

TEAMS	1	2	3	4	5	1	2	3	4	5
Functional Effectiveness										
Design Time	118	56	80	50	89	100	107	47	61	87
Manufact. Cube Size	47	252	12	66	75	53	180	282	4	42
Manufact. Unique Parts	14	5	8	13	5	1	8	12	6	10
Support Moving Parts	3	1	1	5	1	0	1	1	1	2
Labor	396	207	285	174	306	660	684	498	744	606
Material	380	49	81	293	314	37	418	311	43	300
Support LCC	939	376	489	631	766	870	1313	1055	966	1116
Effectiveness										
Range/Accuracy	466	433	500	500	500	500	500	500	500	366
Producability	400	400	300	500	300	500	500	500	500	400
Size	500	100	500	400	400	400	200	500	500	500
System Effectiveness	1366	933	1352	1530	1231	1400	1248	1500	1500	1266
Cost Effectiveness	1.45	2.48	2.76	2.42	1.61	1.61	.95	1.42	1.55	1.13
Process Time	132	69	95	58	102	110	114	83	124	101
Process Cost	506	317	395	284	416	830	854	668	914	776
Elapsed Time (HR:M)	3:11	2:25	2:28	1:43	2:38	3:00	2:37	2:12	2:45	2:26
Elapsed Time (HR)	3.18	2.42	2.47	1.72	2.63	3.00	2.62	2.20	2.75	2.43
Derived Measures										
Dom. Difference	25	8	19	24	54	-	122	93	61	79
Dom. Dispersion	9.03	17.97	6.87	8.52	19.09	-	39.13	26.93	17.77	25.63
Concept/Detail Design	.74	.80	1.11	1.77	1.07	1.22	1.55	1.52	1.07	2.00

E.4. Concurrent Engineering Without Computer Support

Concurrent Engineering Without Computer Support										
	SMALL					LARGE				
TEAMS	1	2	3	4	5	1	2	3	4	5
TEAM NAME	G	N	O	T	U	F	A	J	AA	AL
Concept Design										
Time (CD)	37	22	34	29	37	38	49	47	45	37
Cost (CD)	111	66	102	87	111	228	294	282	270	222
Total Ideas	9	3	7	4	10	10	11	9	11	7
Final Ideas	6	3	4	4	11	4	5	9	11	7
Ideas/Person	2	1	1.67	1.33	1.67	.67	1.17	1	.83	.83
Comments	61					55				
Preliminary Design										
Q1	1.6	1.6	2	2.3	1.6	1.8	1.6	1.5	2.3	1.6
Q2	2.3	2	2.3	2.6	2.3	3.5	2.8	1.8	3	2.3
Q3	1.3	1.3	1.3	2	1.6	3	1.6	1.1	2	1.8
Q4	3	1.6	2.3	2.3	2.3	3	2.3	1.8	2.5	2.3
Q5	2	1.3	1.3	2	1.3	1.5	1.6	1.1	2	1.6
Q6	2	1	1.3	2.6	1.6	2.6	2	1.6	2	1.8
Q7										
Q8										
Q9										
Q10										
Q11										
Q12										
Detail Design										
Time (DD)	58	48	67	51	38	74	60	35	51	33
Cost (DD)	174	144	201	153	114	444	360	210	306	198
Tutorials										
AutoCAD	12	15	14	7	9	20	22	14	6	7
Assembly	9	15	7	10	10	4	14	6	4	7
LCC	12	9	11	9	13	14	11	13	2	7
Final Design										
Q1	1.3	1	2.3	1.6	1.6	2.5	1.5	1.1	1.6	1.5
Q2	1.6	1.6	2	3.3	2.3	2.8	2.5	1.6	2.1	2
Q3	2	1	1.6	1.6	2	2.6	1.3	1.5	1.3	2.1
Q4	2.3	1.3	2	1.6	1.6	3	1.6	1.3	2.3	1.8
Q5	1	1.6	1.6	2	1.6	2.6	1.3	1.3	2.3	1.3
Q6	1.3	1	1	2.3	1.6	3.5	2.1	1.6	1.6	2
Q7	1.6	1	1.3	2.3	2.3	1.6	3	1.6	2.3	2.1
Q8	2.3	1.3	1.3	2	1.3	2.8	1.3	1.8	2.3	1.6
Q9	1.3	1	1.6	1.6	2	2.5	1.6	1.1	1.5	1.5

TEAMS	1	2	3	4	5	1	2	3	4	5
Manufacturing										
Time (MF)	5	8	8	11	4	12	21	19	7	4
Cost (MF)	15	24	24	33	12	72	126	114	42	24
Design Errors	1	1	1	2	1	2	0	2	1	0
Manufacturing Errors	0	0	1	0	0	0	1	0	0	0
Test Readiness										
Q1	1.3	1.6	1.6	2	1.3	3	1.8	1.1	1.8	2
Q2	1.6	1.6	2.3	1.6	2.3	3.5	1.6	1.3	2.3	2.1
Q3	1.6	1	1.3	1.6	1.6	2.6	1.3	1.1	1.8	1.6
Testing										
Time (TE)	9	4	13	4	4	11	8	7	2	2
Cost (TE)	27	12	39	12	12	66	48	42	12	12
Attempts	6	6	6	6	6	6	3	6	6	3
Successes	4	3	4	3	6	5	2	5	3	2
Ind. Questionnaire										
Q1	2	2.6	2.3	2.3	1.3	2.8	2.3	1.8	3	3.3
Q2	1.6	1.6	1.6	2	1.6	3	2.3	1.1	1.6	1.6
Q3	2	2	1.3	1.6	3	2.5	2.8	1.1	2.5	2.8
Q4	1.6	1.3	1	1.6	1.6	1.5	2.3	1	2.3	1.6
Q5	1.6	1	1	1.3	1.6	2.5	1.8	1	1.6	2
Q6	1.6	1	1.3	1.6	1.6	3.5	2.3	1.5	2	1.6
Q7	1.3	1.3	1.3	1.6	1.3	2	2.1	1	2.3	2.3
Q8	2.6	3	2.3	3	2.3	2.6	2.8	3	2.3	2.8
Q9	2.3	2.3	1.3	2.3	3	2.8	2.8	2.3	2.8	3.5
Q10	4	3	2.3	2.6	4	4.3	2.6	2.1	3.3	4
Q11	2.3	1.3	1.6	1.6	3.3	2.5	2.5	3.1	2.3	2.8
Q12	2.3	2	1.6	2	2.3	2.6	2	1.3	2.1	2.1
Team Questionnaire										
Q1	2	2	2	2	1	4	2	2	3	4
Q2	2	1	1	2	2	3	2	1	2	1
Q3	2	1	3	2	2	4	3	1	4	4
Q4	1	1	1	1	2	2	1	1	1	2
Q5	1	1	1	1	2	2	1	1	1	2
Q6	1	1	1	2	2	4	2	2	2	2
Q7	1	1	2	2	1	2	1	1	4	2
SYMLOG										
U	40	52	57	44	51	45	39	52	44	38
D	29	12	13	14	15	26	19	24	15	20
U/D	11U	40U	44U	30U	37U	19U	20U	28U	29U	18U
P	56	52	61	52	56	51	48	55	49	47
N	11	9	4	3	11	19	9	18	8	8
P/N	45P	43P	57P	49P	45P	32P	39P	38P	41P	39P
F	51	47	50	42	56	50	46	51	46	43
B	24	25	30	27	23	26	26	30	22	23
F/B	27F	22F	20F	14F	33F	24F	21F	21F	24F	20F

TEAMS	1	2	3	4	5	1	2	3	4	5
Functional Effectiveness										
Design Time	95	70	101	80	75	112	109	82	96	70
Manufact. Cube Size	73	35	312	38	6	225	195	896	136	24
Manufact. Unique Parts	11	8	11	8	10	14	9	4	14	6
Support Moving Parts	2	1	4	1	1	3	1	1	1	1
Labor	327	246	366	285	249	810	828	648	630	456
Material	837	154	487	158	164	392	592	5	558	110
Support LCC	1307	470	996	513	484	1306	1529	703	1298	632
Effectiveness										
Range/Accuracy	500	500	500	500	500	500	466	500	500	333
Producability	500	400	400	300	500	300	100	200	400	500
Size	400	500	100	500	500	100	200	100	300	500
System Effectiveness	1446	1436	1033	1300	1650	972	766	853	1200	1333
Cost Effectiveness	1.1	3.05	1.03	2.5	3.4	.74	.5	1.21	.92	2.11
Process Time	109	82	122	95	83	135	138	108	105	76
Process Cost	377	296	416	335	299	860	878	698	680	506
Elapsed Time (HR:M)	2:43	2:10	2:40	2:19	2:10	3:06	3:13	2:42	2:31	2:57
Elapsed Time (HR)	2.72	2.17	2.67	2.32	2.17	3.10	3.22	2.70	2.52	2.95
Derived Measures										
Dom. Difference	83	14	8	38	35	124	59	85	71	107
Dom. Dispersion	33.88	5.02	2.94	14.76	14.73	36.88	22.43	25.61	20.43	33.81
Concept/Detail Design	.64	.46	.51	.57	.97	.51	.82	1.34	.88	1.12

E.5. Table of Feasible Ideas

Legend: *O - Idea Built*
X - Idea Had

STANDARDS	A CNL	B CCS	C CCL	D SCL	E SNL	F CNL	G CNS	H SNL	I SCS	J CNL
Car Over Ramp	X	X	X			O	X	X		X
Car Around		O	X		X		X	X	O	X
Catapult	X		X	O	X	X	X	O	X	X
Conveyor	X		O		X				X	
Crane	X			X	X				X	
Flipper Around	X		X	X			O			O
Pendulum Over										
Pendulum Around										
Pulley			X		X	X	X	X		X
Sew-Saw Over	X				O	X				
See-Saw Around										
Slingshot Over	O		X				X			X
Slingshot Around										
Winch										
TOTAL IDEAS	7	2	7	3	6	4	6	4	4	6
IDEAS/PERSON	1.17	0.67	1.17	0.5	1	0.67	2	0.67	1.33	1

STANDARDS	K CCS	L SCS	M SNS	N CNS	O CNS	P CCS	Q SCS	R SCL	S SNS	T CNS
Car Over Ramp	X	X		X				X	X	X
Car Around	X		X		O	X	X	X	X	X
Catapult		X			X		O	X		
Conveyor	X				X			X		
Crane						X			X	
Flipper Around	X	X			X	X		X		
Pendulum Over						X				
Pendulum Around	O					O				X
Pulley								X		
Sew-Saw Over										
See-Saw Around										O
Slingshot Over			X	X	X		X	O		
Slingshot Around		O	O	O						
Winch	X								O	
TOTAL IDEAS	6	4	3	3	5	5	3	7	4	4
IDEAS/PERSON	2	1.33	1	1	1.67	1.67	1	1.17	1.33	1.33

Legend: *O - Idea Built*
X - Idea Had

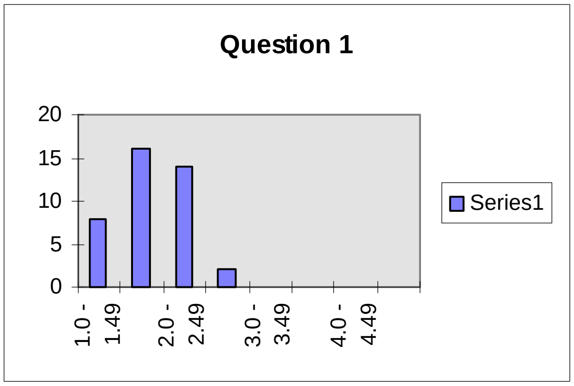
STANDARDS	U CNS	V CCL	W SCL	X CCL	Y SNL	Z CCL	AA CNL	AB SNL	AC SCS	AD SCL
Car Over Ramp	X		X	X	X	X	X	X		X
Car Around		X		X	X	X		X	O	X
Catapult		X	X	X	X	X	X	X	X	X
Conveyor			X	X						
Crane				X						X
Flipper Around	X	X		X	X	X	X		X	X
Pendulum Over							O			
Pendulum Around					O					
Pulley	X	X	X	X				X		
Sew-Saw Over										
See-Saw Around										
Slingshot Over	X		O	X		O		O	X	O
Slingshot Around		O						X		
Winch	O	X		O			X			
TOTAL IDEAS	5	6	5	9	5	5	5	6	4	6
IDEAS/PERSON	1.67	1	0.83	1.5	0.83	0.83	0.83	1	1.33	1

STANDARDS	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
Car Over Ramp		X			X	X			X	X
Car Around		X	O	X		X	X	X	X	
Catapult	X	X	X	O	X	X	O	X	O	
Conveyor	X	X								X
Crane		X			X					
Flipper Around	X	X	X			X		X	X	X
Pendulum Over	X	X					X			
Pendulum Around	X									O
Pulley	X					X				
Sew-Saw Over										
See-Saw Around										
Slingshot Over		X	X			X	X	X		X
Slingshot Around						O		O		
Winch	O	O			O					
TOTAL IDEAS	7	9	4	2	4	7	4	5	4	5
IDEAS/PERSON	1.16	1.5	1.33	.67	1.33	2.33	1.33	.83	.67	.83

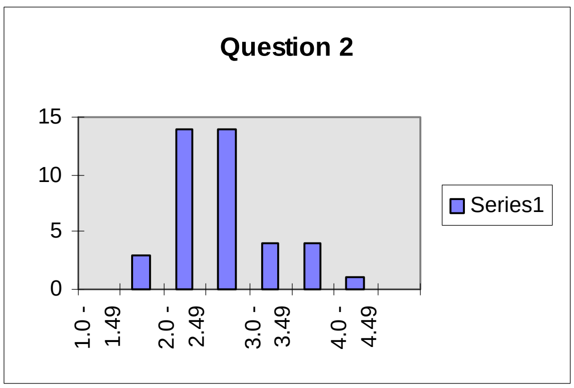
E.6. RESULTS OF SURVEY QUESTIONNAIRES

E.6.1. Preliminary Design Review Questionnaire Results

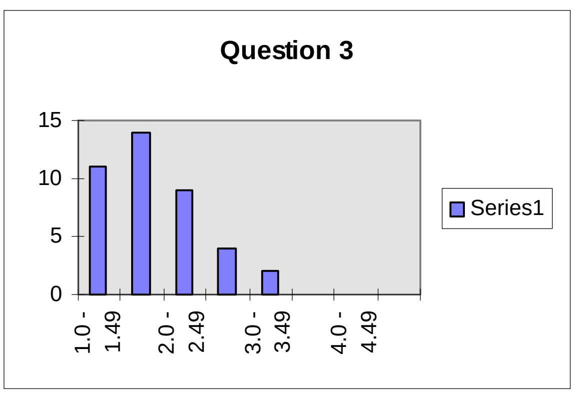
				PRELIMINARY DESIGN QUESTIONNAIRE								
TEAM	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**
I	2.3	2.3	2.6	2.3	2.0	1.6	1.6	3.6	3.6	3.3	3.0	3.0
L	1.6	1.6	1.6	1.3	1.6	1.3	2.3	3.3	3.3	2.6	2.6	2.6
Q	1.3	2.6	1.3	2.0	2.0	2.0	1.6	2.6	3.0	2.6	2.3	2.6
AC	1.6	3.0	1.0	2.0	1.0	1.3	1.6	2.0	2.0	2.0	2.3	2.0
AI	1.3	2.6	1.6	2.3	1.3	1.3	1.6	2.3	2.6	3.0	1.6	2.3
D	2.8	3.8	2.5	2.8	1.3	1.3	2.0	3.0	3.5	2.8	1.6	2.3
R	1.8	4.0	2.0	2.1	1.6	2.0	1.3	2.3	2.6	2.8	2.6	2.5
W	2.3	2.1	1.5	2.0	1.3	1.6	1.3	2.0	2.0	2.5	1.8	2.0
AD	1.5	2.6	2.1	2.3	1.5	1.5	1.6	2.3	2.3	2.3	2.0	2.1
AM	2.3	3.3	3.0	2.3	1.8	2.6	1.6	2.3	2.5	2.1	1.8	2.3
H	1.6	2.3	2.6	2.0	1.3	1.3						
M	1.0	3.6	1.6	1.6	1.0	1.6						
S	2.0	2.0	1.6	1.6	1.6	2.0						
AH	2.3	2.6	2.6	3.0	2.0	2.6						
AK	2.0	2.6	2.3	2.3	1.3	2.0						
E	2.3	2.5	1.8	2.5	2.0	2.3						
Y	1.8	2.1	1.5	1.8	1.3	1.1						
AB	2.3	3.5	1.5	2.0	1.8	1.5						
AE	1.1	2.6	1.3	1.6	1.1	1.3						
AN	1.3	2.5	1.5	2.5	1.3	1.5						
B	2.6	2.3	2.0	3.0	2.0	2.0	2.0	3.0	3.6	3.0	3.3	3.3
K	1.0	1.6	1.3	2.0	1.0	1.0	1.0	3.3	3.3	3.6	2.6	3.0
P	1.3	2.6	1.3	1.0	1.0	1.3	1.3	3.6	4.0	3.6	3.3	3.3
AG	2.3	2.6	1.6	2.3	2.0	2.0	2.0	3.0	3.0	2.6	2.6	2.6
AJ	2.3	2.6	1.0	2.3	1.0	1.3	1.3	2.6	3.0	2.3	2.3	2.0
C	1.8	2.3	2.0	2.8	1.5	1.3	1.6	2.6	2.6	3.0	1.8	2.0
V	1.5	2.3	1.5	2.5	1.5	1.6	1.6	2.3	2.3	1.8	2.1	2.1
X	1.1	2.1	1.3	1.8	1.1	1.3	1.6	2.5	2.3	3.1	1.8	2.1
Z	1.8	3.0	2.3	2.3	1.5	1.6	1.5	2.0	1.8	1.8	1.8	1.8
AF	2.3	2.5	2.1	2.6	1.8	2.0	1.5	2.5	2.1	2.8	1.8	2.5
G	1.6	2.3	1.3	3.0	2.0	2.0						
N	1.6	2.0	1.3	1.6	1.3	1.0						
O	2.0	2.3	1.3	2.3	1.3	1.3						
T	2.3	2.6	2.0	2.3	2.0	2.6						
U	1.6	2.3	1.6	2.3	1.3	1.6						
F	1.8	3.5	3.0	3.0	1.5	2.6						
A	1.6	2.8	1.6	2.3	1.6	2.0						
J	1.5	1.8	1.1	1.8	1.1	1.6						
AA	2.3	3.0	2.0	2.5	2.0	2.0						
AL	1.6	2.3	1.8	2.3	1.6	1.8						
MEANS	1.810	2.575	1.773	2.208	1.505	1.690	1.595	2.655	2.77	2.68	2.25	2.42
STDDEV	0.463	0.554	0.522	0.463	0.347	0.447	0.300	0.510	0.630	0.528	0.534	0.446



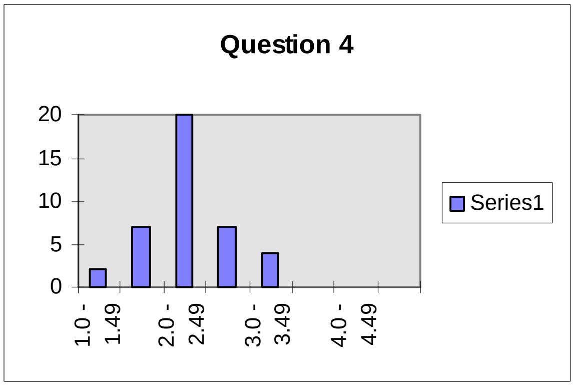
System will meet performance requirements.



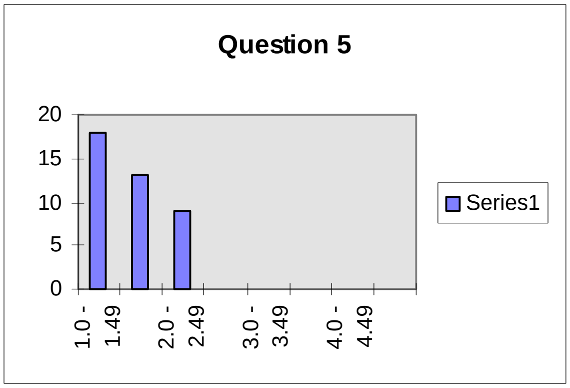
No one has emerged as the leader .



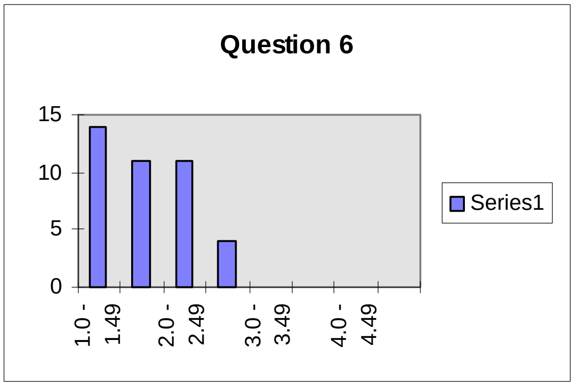
Team effort with contributions from all members.



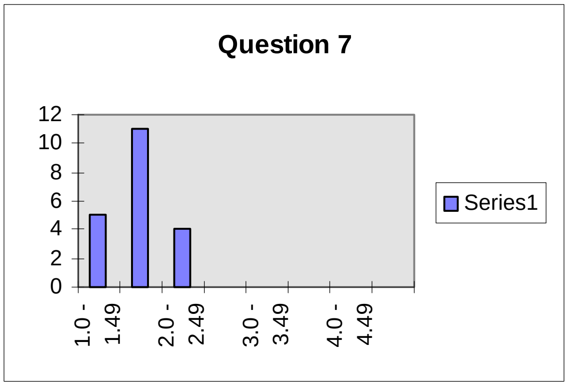
Each member achieved functional goals.



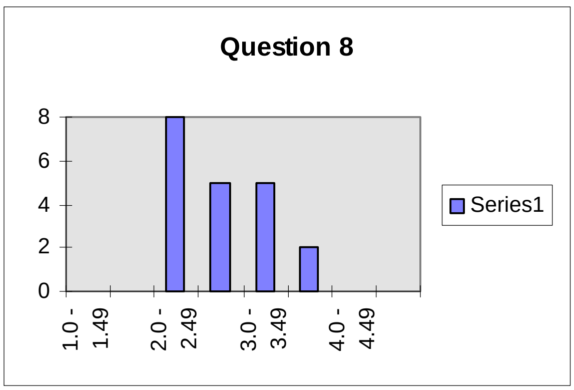
I support the team's decision on the system concept.



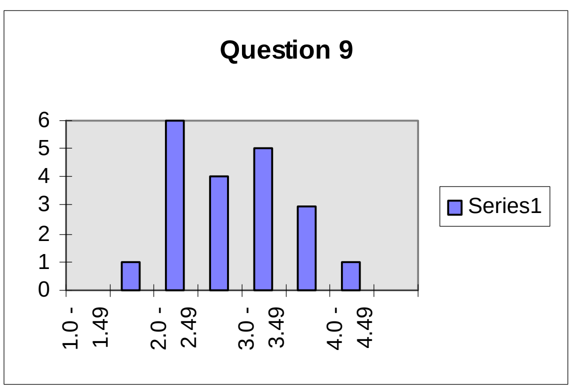
Interaction was outstanding with little conflict.



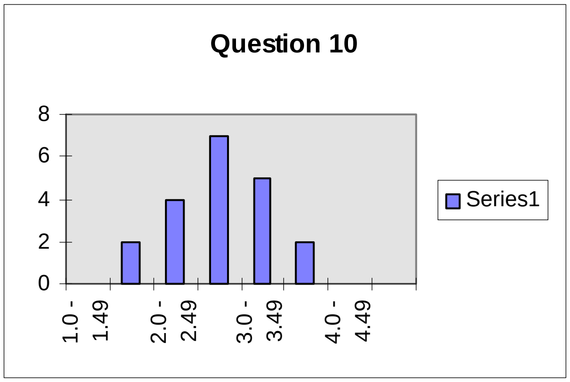
Groupware was easy to use.



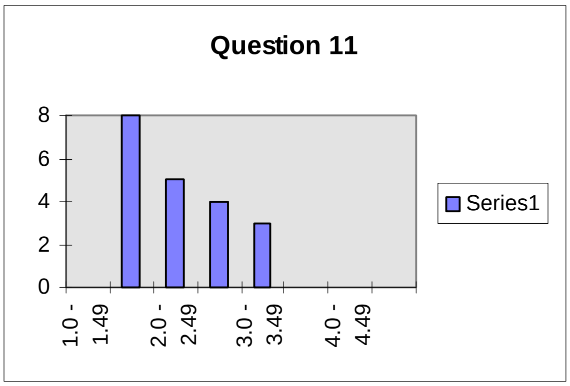
Groupware improved our efficiency.



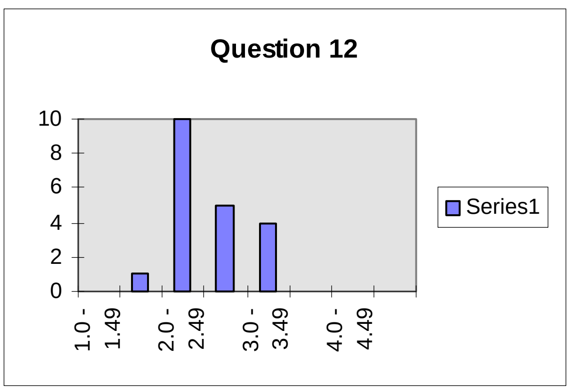
Groupware improved our effectiveness.



Groupware improved our productivity.



Groupware improved everyone's contribution.



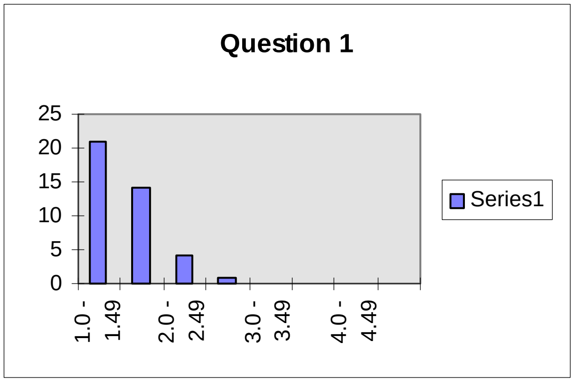
I was extremely satisfied with groupware.

E.6.1.1. Small and Large Group Groupware Analysis

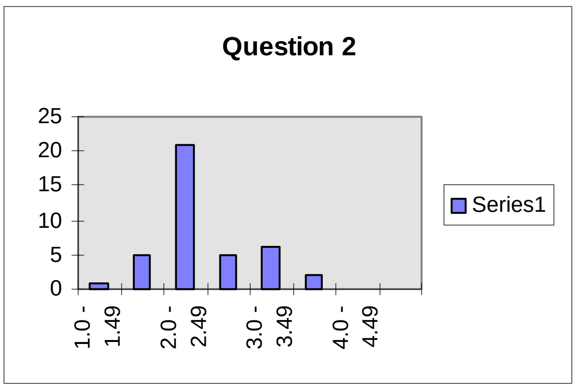
GROUP			PRELIMINARY DESIGN QUESTIONS				
SIZE	**7**	**8**	**9**	**10**	**11**	**12**	**AVE**
Small Averages	1.77	2.97	3.17	2.90	2.63	2.70	2.69
Small Std Deviation	0.90	1.10	1.02	0.96	1.10	0.95	0.80
Large Averages	1.63	2.33	2.38	2.55	1.97	2.23	2.18
Large Std Deviation	0.61	1.11	1.08	0.98	0.84	0.89	0.65
AVERAGES	1.68	2.54	2.64	2.67	2.19	2.39	2.35
STANDARD DEV.	0.72	1.14	1.11	0.98	0.98	0.93	0.74

E.6.2. Final Design Review Questionnaire Results

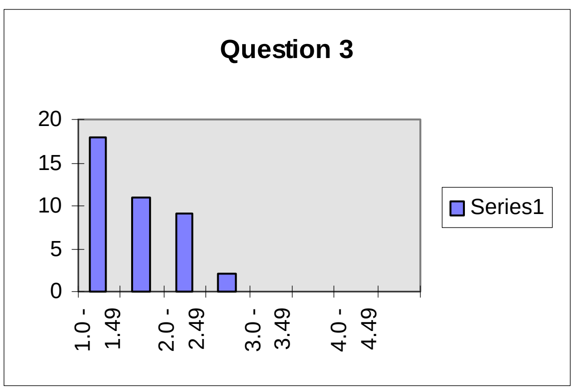
				FINAL DESIGN QUESTIONNAIRE					
TEAM	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**
I	1.3	2.0	1.3	1.6	4.0	3.3	3.0	3.0	1.3
L	2.0	2.0	1.3	1.6	1.6	1.6	1.6	1.6	1.3
Q	1.0	3.0	2.0	1.6	2.0	2.0	2.0	2.0	1.3
AC	1.0	2.0	1.3	1.0	1.6	1.6	1.6	1.3	1.3
AI	1.0	2.3	1.0	1.0	2.0	2.0	2.3	1.0	1.3
D	1.5	2.6	1.5	1.3	1.0	1.3	2.5	1.5	1.3
R	1.5	3.6	1.6	1.6	1.8	1.8	1.3	1.3	1.5
W	1.3	2.3	1.6	1.5	1.6	1.6	1.6	1.6	1.1
AD	1.6	3.0	2.1	1.6	2.0	1.8	2.1	1.6	1.8
AM	1.3	2.3	2.0	2.3	2.1	1.6	2.1	1.8	1.6
H	1.3	2.3	1.3	1.6	2.3	2.0	2.0	2.0	1.0
M	1.3	3.3	1.3	2.0	3.0	1.0	1.3	1.6	1.6
S	1.6	2.3	1.6	1.6	1.6	1.6	1.6	1.6	1.6
AH	1.3	3.0	1.6	2.6	2.3	1.6	1.6	2.0	2.6
AK	1.6	1.3	1.0	1.6	2.0	2.0	1.6	2.0	1.3
E	1.6	2.6	2.3	2.6	2.1	1.8	2.3	2.6	2.0
Y	1.3	2.0	1.1	1.5	1.6	1.5	1.3	1.3	1.1
AB	2.1	3.5	1.8	1.8	1.8	1.3	1.5	1.5	1.8
AE	1.1	2.1	1.3	1.3	1.1	1.3	1.8	1.3	1.1
AN	1.1	2.0	1.3	1.8	2.6	2.1	1.6	1.6	1.5
B	2.3	2.3	2.6	1.3	1.3	2.0	2.0	1.3	1.6
K	1.0	1.6	1.3	1.0	1.3	1.6	1.3	1.0	1.0
P	1.6	3.3	2.0	1.0	1.3	1.6	1.6	1.0	1.6
AG	1.3	2.0	1.0	1.3	3.3	1.6	1.6	2.0	1.3
AJ	1.6	2.3	1.0	2.3	1.3	1.3	1.6	1.3	1.3
C	1.8	1.8	2.0	1.8	2.0	2.3	2.3	1.3	1.1
V	1.0	2.1	1.3	2.0	1.5	2.0	2.0	1.8	1.5
X	1.0	2.1	1.0	1.3	2.8	2.0	2.0	1.6	1.3
Z	1.1	2.3	1.6	1.6	1.8	1.6	1.6	1.5	1.5
AF	1.3	2.6	1.6	1.8	1.5	2.3	2.3	1.5	1.5
G	1.3	1.6	2.0	2.3	1.0	1.3	1.6	2.3	1.3
N	1.0	1.6	1.0	1.3	1.6	1.0	1.0	1.3	1.0
O	2.3	2.0	1.6	2.0	1.6	1.0	1.3	1.3	1.6
T	1.6	3.3	1.6	1.6	2.0	2.3	2.3	2.0	1.6
U	1.6	2.3	2.0	1.6	1.6	1.6	2.3	1.3	2.0
F	2.5	2.8	2.6	3.0	2.6	3.5	1.6	2.8	2.5
A	1.5	2.5	1.3	1.6	1.3	2.1	3.0	1.3	1.6
J	1.1	1.6	1.5	1.3	1.3	1.6	1.6	1.8	1.1
AA	1.6	2.1	1.3	2.3	2.3	1.6	2.3	2.3	1.5
AL	1.5	2.0	2.1	1.8	1.3	2.0	2.1	1.6	1.5
MEANS	1.445	2.343	1.568	1.693	1.870	1.778	1.853	1.663	1.470
STDDEV	0.384	0.559	0.435	0.463	0.637	0.510	0.453	0.464	0.355



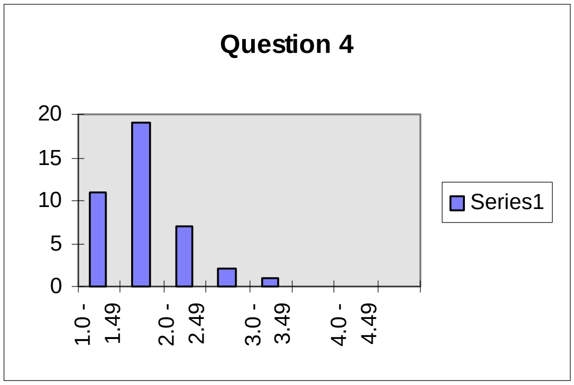
System will meet performance requirements.



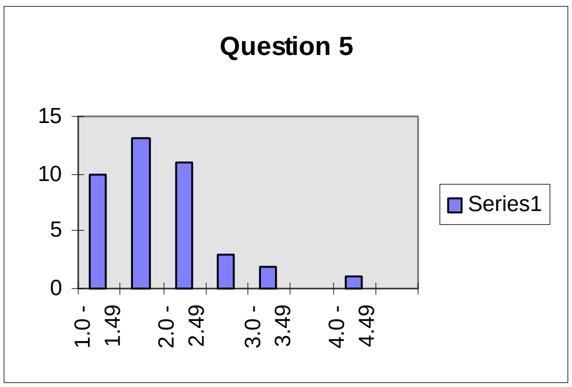
No one has emerged as the leader.



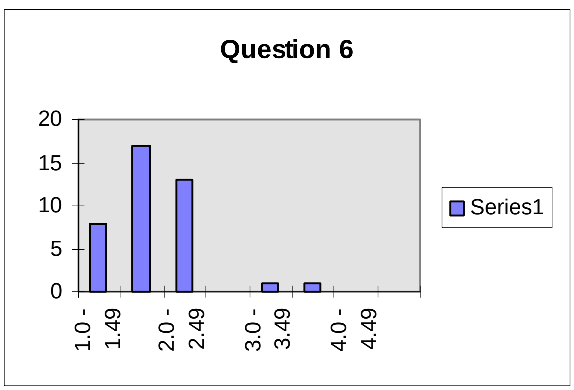
Team effort with contributions from all members.



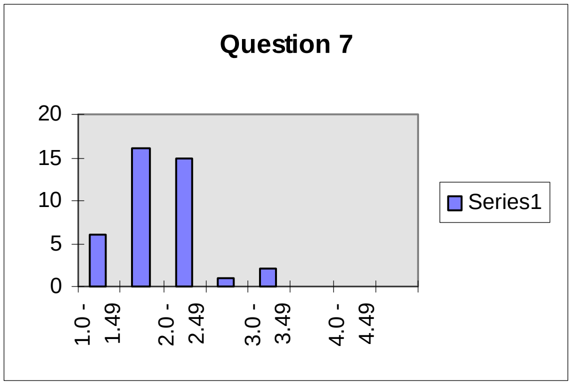
Each member achieved his functional goals.



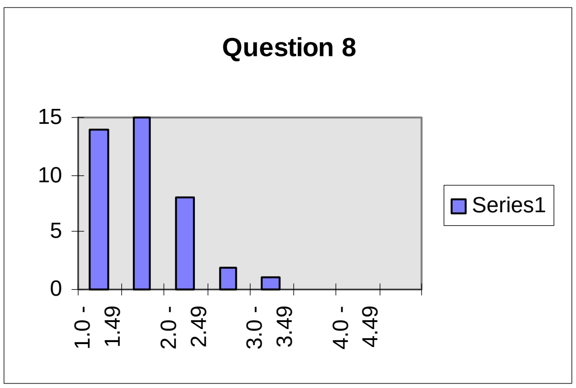
Life-cycle cost influenced the design.



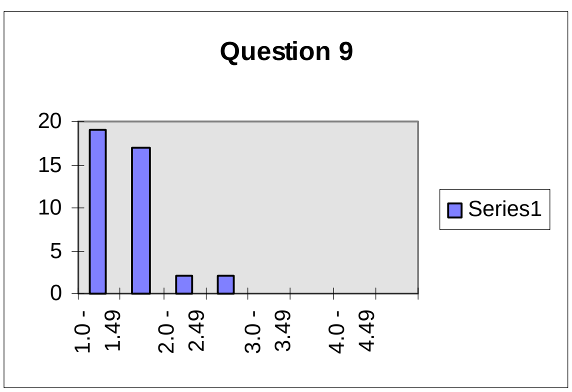
Manufacturing influenced the design.



Design influenced the design.



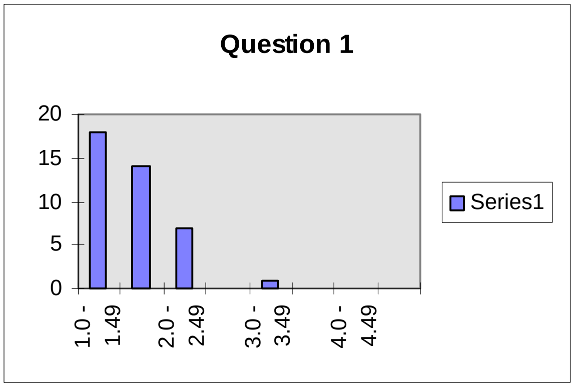
I achieved my functional role's objective.



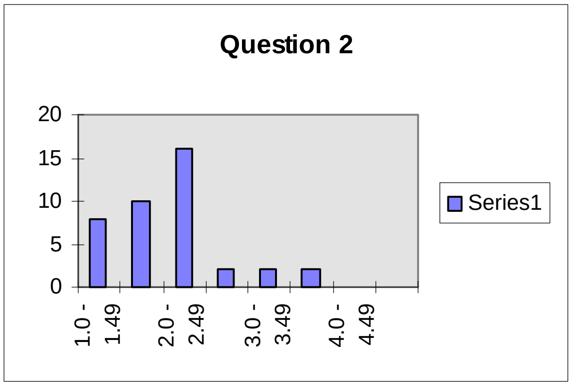
Interaction was outstanding with little conflict.

E.6.3. Test Readiness Review Questionnaire Results

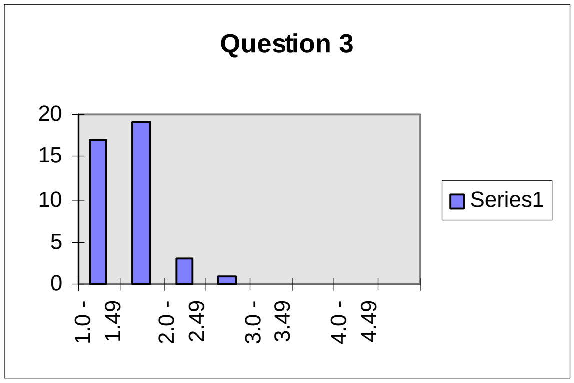
				TEST READINESS QUESTIONNAIRE			
TEAM	**Q1**	**Q2**	**Q3**				
I	1.6	2.0	2.0				
L	1.3	2.0	1.0				
Q	1.0	2.3	1.6				
AC	1.3	1.0	1.0				
AI	1.0	3.6	1.3				
D	1.6	3.0	1.3				
R	1.1	2.1	1.6				
W	1.5	2.0	1.5				
AD	1.3	2.5	1.6				
AM	1.8	2.1	2.1				
H	1.6	1.3	1.0				
M	1.3	2.6	1.6				
S	1.6	1.6	1.6				
AH	1.3	2.3	1.6				
AK	2.0	2.0	1.0				
E	2.3	2.3	2.1				
Y	1.3	1.3	1.0				
AB	2.0	1.8	1.5				
AE	1.1	1.0	1.0				
AN	1.5	1.5	1.3				
B	2.3	1.6	1.6				
K	1.6	2.0	1.3				
P	1.3	1.0	1.3				
AG	1.3	2.0	1.6				
AJ	1.6	2.3	1.0				
C	1.5	1.8	1.6				
V	1.1	1.5	1.5				
X	1.0	1.1	1.0				
Z	1.1	1.3	1.5				
AF	2.3	3.0	1.8				
G	1.3	1.6	1.6				
N	1.6	1.6	1.0				
O	1.6	2.3	1.3				
T	2.0	1.6	1.6				
U	1.3	2.3	1.6				
F	3.0	3.5	2.6				
A	1.8	1.6	1.3				
J	1.1	1.3	1.1				
AA	1.8	2.3	1.8				
AL	2.0	2.1	1.6				
MEANS	1.553	1.953	1.460				
STDDEV	0.434	0.626	0.362				



System will meet performance requirements.



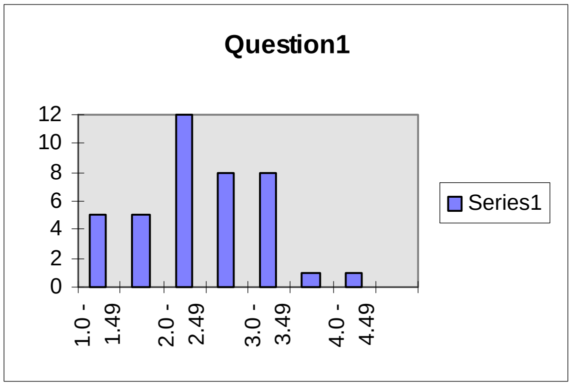
We designed as good a system as we were capable of.



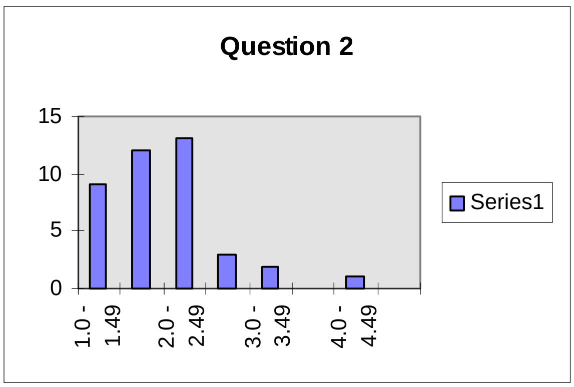
Each member made a significant contribution.

E.6.4. Individual Post-Experiment Questionnaire Results

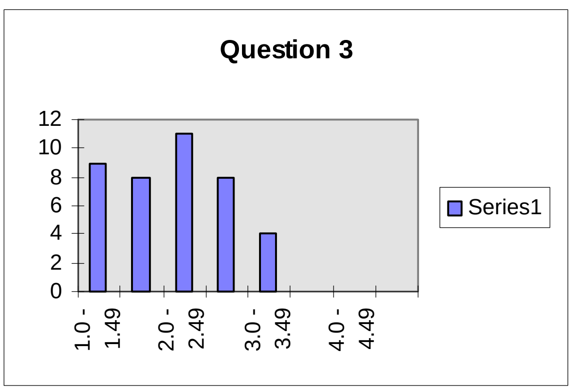
		INDIVIDUAL POST-EXPERIMENT QUESTIONNAIRE										
TEAM	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**
I	2.3	2.0	2.6	1.0	1.0	1.6	1.0	3.0	3.0	2.6	2.3	2.0
L	1.6	1.3	1.3	1.0	1.0	1.0	1.0	3.0	3.0	3.0	1.6	2.0
Q	2.3	2.0	1.6	1.6	1.6	1.6	2.0	3.3	3.0	2.6	2.3	2.0
AC	1.3	1.0	1.0	1.0	1.0	1.0	1.0	3.0	3.0	2.6	2.0	1.0
AI	4.0	2.3	1.6	1.3	1.3	2.6	2.6	2.0	2.6	3.3	2.0	2.0
D	2.3	2.1	2.5	1.3	1.3	1.8	1.5	3.0	2.5	3.8	3.5	2.6
R	2.5	3.0	3.0	1.1	1.3	1.8	1.5	3.0	2.6	4.0	1.8	3.0
W	2.1	2.0	2.0	1.3	1.3	1.6	1.6	3.6	3.5	3.5	2.0	2.3
AD	2.8	2.3	2.1	1.5	1.6	1.8	1.8	2.8	2.5	4.1	3.1	2.6
AM	3.1	2.1	2.5	1.6	2.3	1.8	2.1	2.5	2.3	3.5	2.0	2.1
H	3.0	1.6	1.6	1.0	1.0	1.0	1.6	3.0	1.3	2.6	3.0	2.0
M	2.0	2.3	2.0	1.0	1.6	2.3	1.0	2.3	2.6	2.6	1.6	1.3
S	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2.6	3.0	3.0	2.3	1.6
AH	3.6	4.0	3.3	2.6	2.0	3.6	1.6	2.0	2.0	3.0	2.3	3.0
AK	1.0	1.0	1.3	1.0	1.0	1.3	1.3	2.6	3.0	3.3	2.0	1.3
E	3.0	2.0	3.0	1.8	2.1	2.0	1.8	3.1	2.6	4.5	3.0	2.8
Y	3.0	1.1	2.1	1.3	1.1	1.0	1.3	3.1	2.6	3.5	2.0	1.8
AB	1.6	1.3	2.0	1.5	1.3	1.8	1.5	2.5	2.3	3.3	2.6	1.8
AE	1.1	1.0	1.0	1.0	1.0	1.0	1.0	2.1	2.0	2.0	2.1	1.3
AN	2.0	1.5	1.8	1.5	1.5	2.1	1.5	2.8	2.8	3.3	2.0	2.1
B	2.6	2.6	2.0	1.3	2.0	1.6	1.6	3.0	3.3	4.3	2.6	2.6
K	2.6	1.3	1.3	1.0	1.0	1.3	2.0	3.6	3.3	4.0	2.3	2.0
P	1.3	1.6	1.3	1.3	1.3	2.0	1.0	1.6	1.6	1.3	1.0	1.3
AG	2.3	2.6	2.3	1.3	1.3	1.0	1.3	3.0	2.6	1.6	3.0	2.0
AJ	3.3	2.0	2.3	1.3	1.3	1.6	1.3	3.0	2.0	1.6	1.6	2.3
C	2.5	1.6	1.8	1.6	1.6	1.5	1.5	2.6	2.6	3.5	2.8	2.6
V	2.3	2.0	1.8	1.5	1.6	2.1	1.5	2.3	2.1	4.3	3.0	2.0
X	2.6	1.1	2.3	1.1	1.1	1.8	1.1	2.8	2.5	4.1	2.8	2.1
Z	1.5	1.6	1.3	1.3	1.5	1.3	1.1	2.6	2.8	3.1	2.0	1.8
AF	3.3	2.8	2.8	1.8	1.8	1.8	2.3	3.0	3.1	4.1	2.6	2.5
G	2.0	1.6	2.0	1.6	1.6	1.6	1.3	2.6	2.3	4.0	2.3	2.3
N	2.6	1.6	2.0	1.3	1.0	1.0	1.3	3.0	2.3	3.0	1.3	2.0
O	2.3	1.6	1.3	1.0	1.0	1.3	1.3	2.3	1.3	2.3	1.6	1.6
T	2.3	2.0	1.6	1.6	1.3	1.6	1.6	3.0	2.3	2.6	1.6	2.0
U	1.3	1.6	3.0	1.6	1.6	1.6	1.3	2.3	3.0	4.0	3.3	2.3
F	2.8	3.0	2.5	1.5	2.5	3.5	2.0	2.6	2.8	4.3	2.5	2.6
A	2.3	2.3	2.8	2.3	1.8	2.3	2.1	2.8	2.8	2.6	2.5	2.0
J	1.8	1.1	1.1	1.0	1.0	1.5	1.0	3.0	2.3	2.1	3.1	1.3
AA	3.0	1.6	2.5	2.3	1.6	2.0	2.3	2.3	2.8	3.3	2.3	2.1
AL	3.3	1.6	2.8	1.6	2.0	1.6	2.3	2.8	3.5	4.0	2.8	2.1
MEANS	2.355	1.868	2.018	1.408	1.445	1.708	1.538	2.738	2.588	3.205	2.313	2.053
STDDEV	0.713	0.639	0.618	0.380	0.395	0.584	0.429	0.422	0.517	0.826	0.576	0.477



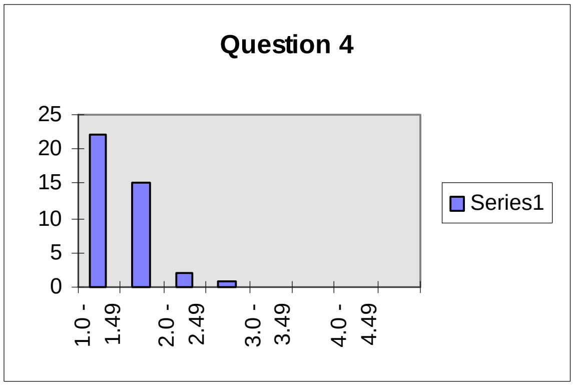
We designed the best system we could have.



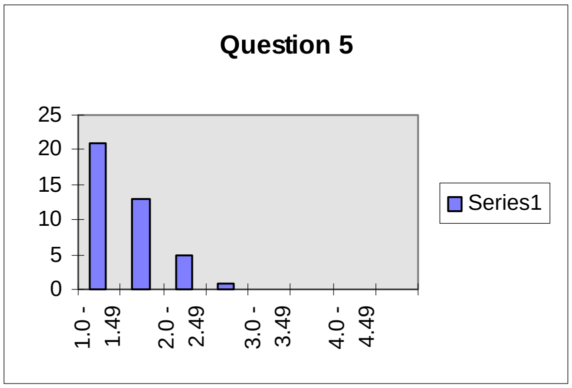
I was satisfied with the process to create ideas.



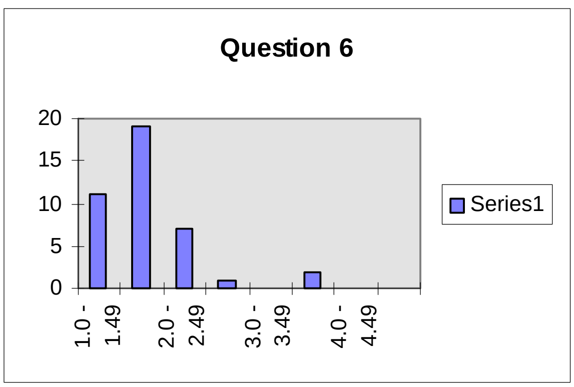
I was satisfied with the process to do detail design.



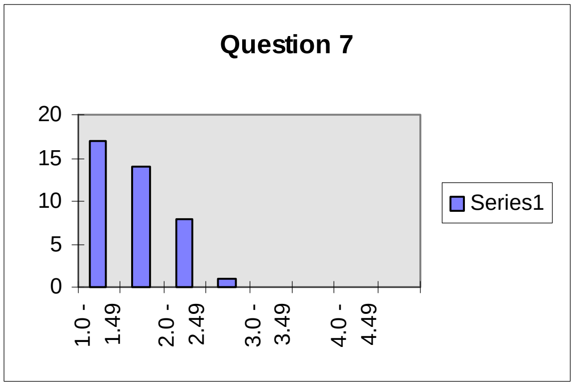
Everyone was given a chance to make a contribution.



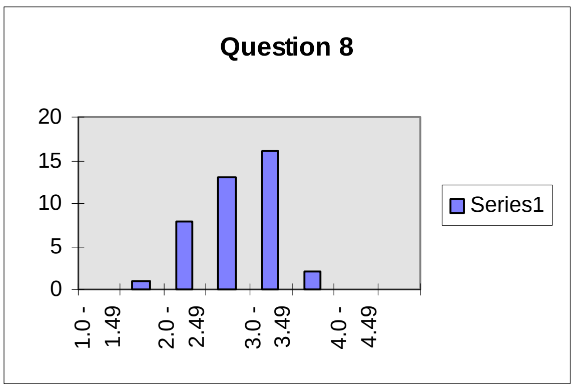
Everyone contributed to the final product.



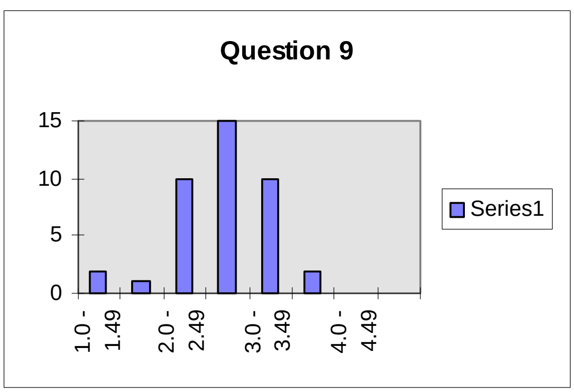
There was little discussion conflict.



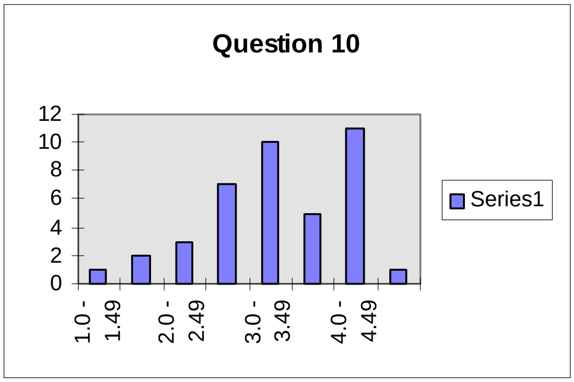
I agreed with the final system we developed.



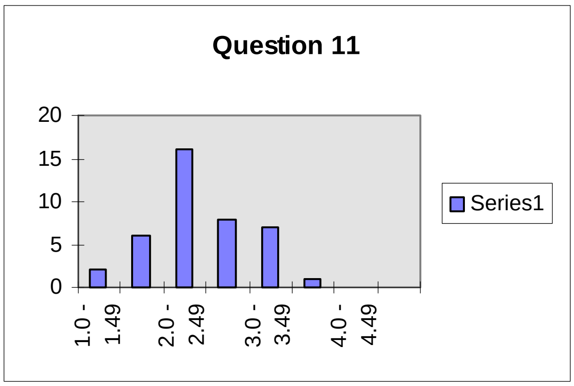
On a team, I’m usually the leader.



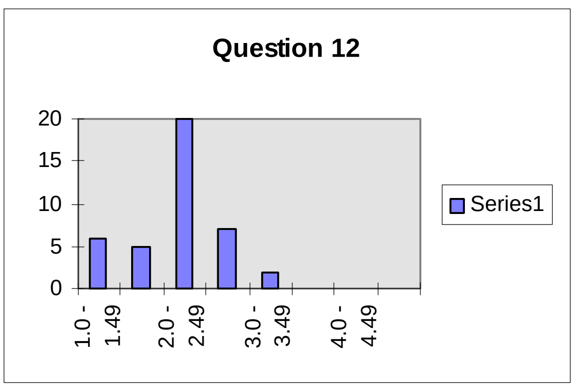
I’m usually very outspoken.



I know my team members very well.



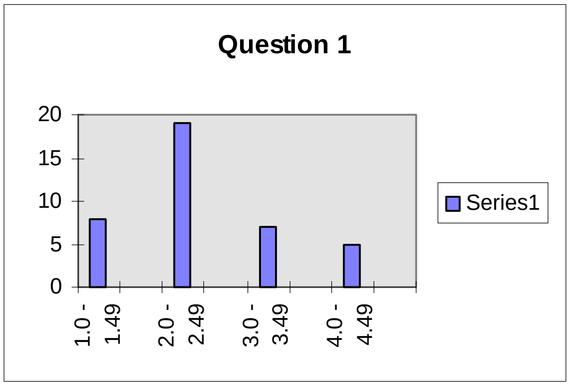
AutoCAD is an important part of design.



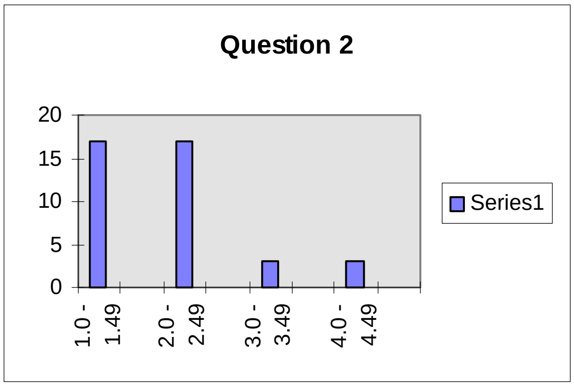
I was extremely satisfied with the entire process.

E.6.5. Team Post-Experiment Questionnaire Results

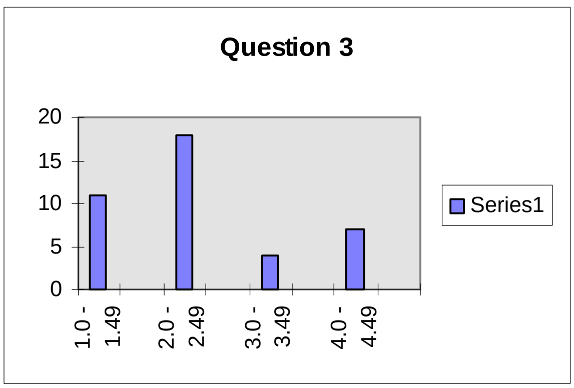
			TEAM POST-EXPERIMENT QUESTIONNAIRE				
TEAM	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**
I	3.0	2.0	2.0	1.0	1.0	1.0	1.0
L	1.0	2.0	2.0	1.0	1.0	1.0	1.0
Q	1.0	1.0	2.0	1.0	1.0	1.0	1.0
AC	2.0	1.0	1.0	1.0	1.0	1.0	1.0
AI	5.0	4.0	2.0	1.0	1.0	1.0	1.0
D	2.0	3.0	4.0	1.0	1.0	1.0	2.0
R	2.0	4.0	2.0	2.0	2.0	2.0	2.0
W	2.0	2.0	1.0	1.0	1.0	1.0	1.0
AD	2.0	2.0	3.0	1.0	1.0	1.0	2.0
AM	3.0	2.0	3.0	2.0	2.0	2.0	2.0
H	3.0	1.0	2.0	1.0	1.0	1.0	1.0
M	2.0	1.0	1.0	1.0	1.0	2.0	1.0
S	1.0	1.0	1.0	1.0	1.0	1.0	1.0
AH	4.0	4.0	2.0	2.0	2.0	4.0	2.0
AK	1.0	1.0	1.0	1.0	1.0	1.0	1.0
E	2.0	2.0	4.0	1.0	1.0	1.0	1.0
Y	3.0	1.0	2.0	1.0	1.0	1.0	1.0
AB	2.0	1.0	2.0	1.0	1.0	2.0	2.0
AE	1.0	1.0	1.0	1.0	1.0	1.0	1.0
AN	2.0	2.0	1.0	1.0	1.0	2.0	1.0
B	2.0	2.0	2.0	1.0	1.0	2.0	2.0
K	4.0	2.0	2.0	1.0	1.0	2.0	2.0
P	1.0	1.0	1.0	1.0	1.0	2.0	1.0
AG	2.0	3.0	2.0	1.0	1.0	1.0	1.0
AJ	4.0	2.0	4.0	1.0	1.0	1.0	2.0
C	2.0	1.0	1.0	1.0	1.0	1.0	1.0
V	2.0	2.0	2.0	1.0	1.0	1.0	1.0
X	3.0	1.0	4.0	1.0	1.0	1.0	1.0
Z	1.0	1.0	2.0	1.0	1.0	1.0	1.0
AF	3.0	2.0	2.0	2.0	1.0	1.0	3.0
G	2.0	2.0	2.0	1.0	1.0	1.0	1.0
N	2.0	1.0	1.0	1.0	1.0	1.0	1.0
O	2.0	1.0	3.0	1.0	1.0	1.0	2.0
T	2.0	2.0	2.0	1.0	1.0	2.0	2.0
U	1.0	2.0	2.0	2.0	2.0	2.0	1.0
F	4.0	3.0	4.0	2.0	2.0	4.0	2.0
A	2.0	2.0	3.0	1.0	1.0	2.0	1.0
J	2.0	1.0	1.0	1.0	1.0	2.0	1.0
AA	3.0	2.0	4.0	1.0	1.0	2.0	4.0
AL	4.0	1.0	4.0	2.0	2.0	2.0	2.0
MEANS	2.300	1.800	2.175	1.175	1.150	1.500	1.450
STDDEV	1.018	0.883	1.035	0.385	0.362	0.751	0.677



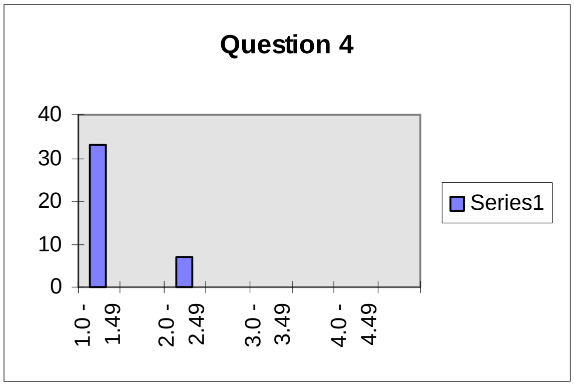
We designed the best system we could have.



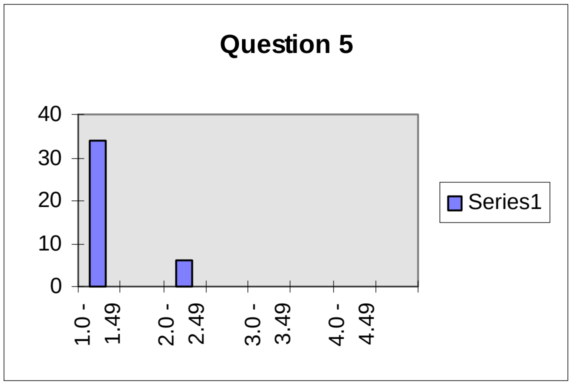
We were satisfied with the process to create ideas.



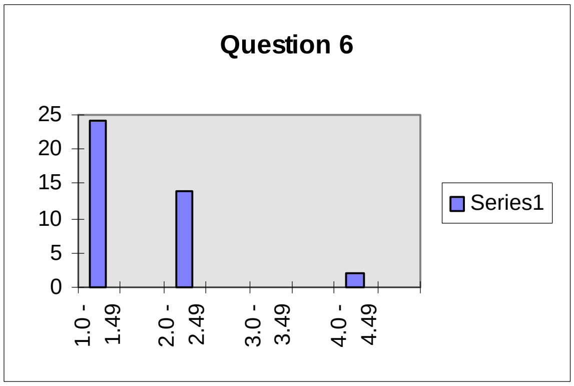
We were satisfied with the process to do detail design.



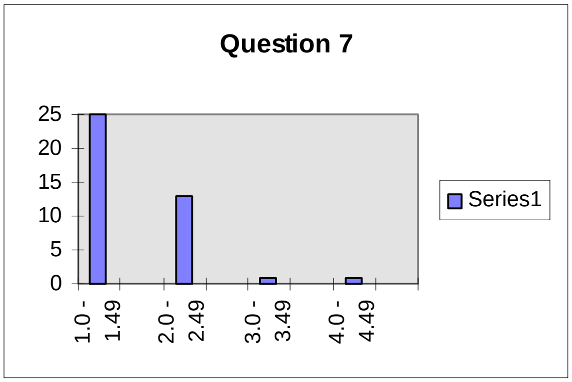
Everyone was given a chance to make a contribution.



Everyone contributed to the final product.



There was little discussion conflict.



We all agreed with the final system we developed.

E.7. Satisfaction Data Analysis

TEAM NAME	D1	D2	D	M1	M2	M	S1	S2	S	AVE
D-SCL-1-1	2	2	2	4	2	3	4	2	3	2.67
H-SNS-1-2	3		3	1		1	2		2	2
F-CNL-1-3	3	2	2.5	5	2	3.5	3	1	2	2.67
B-CCS-1-4	2		2	2		2	4		4	2.67
I-SCS-1-5	1		1	2		2	3		3	2
E-SNL-1-6	3	4	3.5	2	4	3	2	2	2	2.83
C-CCL-1-7	3	2	2.5	2	4	3	2	3	2.5	2.67
A-CNL-2-8	2	2	2	2	2	2	2	2	2	2
G-CNS-1-9	3		3	2		2	2		2	2.33
J-CNL-3-10	2	1	1.5	2	1	1.5	1	1	1	1.33
K-CCS-2-11	2		2	2		2	2		2	2
L-SCS-2-12	3		3	1		1	2		2	2
M-SNS-2-13	2		2	1		1	1		1	1.33
N-CNS-2-14	2		2	2		2	2		2	2
O-CNS-3-15	1		1	2		2	2		2	1.67
P-CCS-3-16	2		2	1		1	1		1	1.33
Q-SCS-3-17	2		2	2		2	2		2	2
R-SCL-2-18	3	2	2.5	4	4	4	3	2	2.5	3
S-SNS-3-19	1		1	2		2	2		2	1.67
T-CNS-4-20	2		2	2		2	2		2	2
U-CNS-5-21	3		3	2		2	2		2	2.33
V-CCL-2-22	2	2	2	2	2	2	2	2	2	2
W-SCL-3-23	4	2	3	2	2	2	2	2	2	2.33
X-CCL-3-24	3	3	3	1	3	2	2	1	1.5	2.17
Y-SNL-2-25	2	2	2	2	1	1.5	2	2	2	1.83
Z-CCL-4-26	2	1	1.5	2	2	2	2	2	2	1.83
AA-CNL-4-27	2	2	2	2	2	2	2	3	2.5	2.17
AB-SNL-3-28	2	1	1.5	2	2	2	2	2	2	1.83
AC-SCS-4-29	1		1	1		1	1		1	1
AD-SCL-4-30	3	4	3.5	2	1	1.5	4	2	3	2.67
AE-SNL-4-31	1	1	1	1	2	1.5	1	2	1.5	1.33
AF-CCL-5-32	2	3	2.5	2	4	3	2	2	2	2.5
AG-CCS-4-33	2		2	2		2	2		2	2
AH-SNS-4-34	3		3	4		4	2		2	3
AI-SCS-5-35	1		1	2		2	3		3	2
AJ-CCS-5-36	2		2	3		3	2		2	2.33
AK-SNS-5-37	1		1	2		2	1		1	1.33
AL-CNL-5-38	2	2	2	2	2	2	3	2	2.5	2.17
AM-SCL-5-39	3	2	2.5	2	2	2	2	2	2	2.17
AN-SNL-5-40	2	3	2.5	2	2	2	2	2	2	2.17
MEANS			2.11			2.09			2.05	2.08

E.8. Degree Data Analysis

TEAM NAME	DEGREE PROGRAM						TEAM CLASS.
	D1	D2	M1	M2	S1	S2	
D-SCL-1-1	ISE(ME)		ISE(IE)		ISE(ME)		ENG
H-SNS-1-2	ISE(IE)		ISE		ISE(IE)		ENG
F-CNL-1-3	ISE(IE)	ISE(M)	ISE(M)	ISE(MET)	ISE	ISE(AU)	ENG
B-CCS-1-4	ISE(ME)		ISE(IE)		ISE(IE)		ENG
I-SCS-1-5	ISE		ISE(M)		ISE(M)		ENG
E-SNL-1-6	EM	ISE(IE)	ISE	ISE(MM)	ISE(M)	ISE(M)	ENG
C-CCL-1-7	ISE(IE)	ISE(IE)	ISE(IE)	ISE(IE)	ISE(IE)	ISE(IE)	ENG
A-CNL-2-8	ISE(IE)	ISE(IE)	ISE	ISE(AE)	ISE(IE)	ISE(IE)	ENG
G-CNS-1-9	ISE(ME)		ISE(ME)		ISE(EE)		ENG
J-CNL-3-10	BC	BC	BC	U	BC	BC	BC
K-CCS-2-11	BC		BC		BC		BC
L-SCS-2-12	CE		ISE		BC		ENG
M-SNS-2-13	CE		CE		BC		ENG
N-CNS-2-14	BC		BC		BC		BC
O-CNS-3-15	BC		BC		BC		BC
P-CCS-3-16	BC		BC		BC		BC
Q-SCS-3-17	A		BC		BC		BC
R-SCL-2-18	BC	BC	BC	BC	BC	BC	BC
S-SNS-3-19	BC		BC		BC		BC
T-CNS-4-20	A		A		BC		BC/ENG
U-CNS-5-21	BC		ISE(IE)		BC		BC
V-CCL-2-22	BC	BC	BC	BC	CE	BC	BC
W-SCL-3-23	BC	BC	BC	BC	BC	BC	BC
X-CCL-3-24	CE	A	BC	BC	A	BC	BC/ENG
Y-SNL-2-25	BC	BC	BC	BC	BC	BC	BC
Z-CCL-4-26	BC	BC	BC	BC	BC	BC	BC
AA-CNL-4-27	BC	BC	BC	BC	CE	BC	BC
AB-SNL-3-28	BC	A	BC	BC	BC	BC	BC
AC-SCS-4-29	BC		A		BC		BC
AD-SCL-4-30	BC	BC	BC	BC	BC	BC	BC
AE-SNL-4-31	BC	A	BC	BC	BC	BC	BC
AF-CCL-5-32	BC	BC	BC	BC	ISE(EM)	BC	BC/ENG
AG-CCS-4-33	BC		BC		BC		BC
AH-SNS-4-34	BC		A		BC		BC
AI-SCS-5-35	BC		ISE(CHE)		ISE(EE)		ENG
AJ-CCS-5-36	ISE		ISE		ISE		ENG
AK-SNS-5-37	BC		ISE		BC		BC/ENG
AL-CNL-5-38	CE	ISE	ISE	CE	CE	ISE	ENG
AM-SCL-5-39	ME	ME	ISE	EE	CHE	CE	ENG
AN-SNL-5-40	ISE	ISE	CPE	CPE	CPE	CPE	ENG

Legend:	A	Architecture	AE	Automotive Eng.	AU	Automotive Eng.
	BC	Building Const.	CE	Civil Engineering	CHE	Chemical Engineering
	CPE	Computer Eng.	EE	Electrical Eng.	EM	Engineering. Mechanics
	ISE/IE	Industrial Eng.	M	Mathematics	ME	Mechanical Eng.
	MET	Metallurgy	MM	Mining and Mat.	U	Unknown

Note: Undergraduate degrees of graduate students (when available) are shown in parentheses

Teams with both BC and ENG team classifications correspond to the two types of analyses done to differentiate building construction teams and engineering teams. For one analysis these four teams were considered BC teams. For the other analysis, they were considered engineering teams.

E.9. Team Nationality Analysis

TEAM	NATIONALITY						INTER.
NAME	D1	D2	M1	M2	S1	S2	%
D-SCL-1-1	X	X			X	X	67
H-SNS-1-2			X		X		33
F-CNL-1-3	X	X	X	X		X	84
B-CCS-1-4	X		X				67
I-SCS-1-5	X		X				67
E-SNL-1-6				X			16
C-CCL-1-7		X	X	X	X		67
A-CNL-2-8	X	X	X	X	X	X	100
G-CNS-1-9			X		X		67
J-CNL-3-10							0
K-CCS-2-11							0
L-SCS-2-12							0
M-SNS-2-13			X		X		67
N-CNS-2-14							0
O-CNS-3-15							0
P-CCS-3-16					X		33
Q-SCS-3-17							0
R-SCL-2-18							0
S-SNS-3-19							0
T-CNS-4-20							0
U-CNS-5-21							0
V-CCL-2-22					X		16
W-SCL-3-23	X						33
X-CCL-3-24							0
Y-SNL-2-25				X			16
Z-CCL-4-26							0
AA-CNL-4-27				X			16
AB-SNL-3-28							0
AC-SCS-4-29			X				33
AD-SCL-4-30							0
AE-SNL-4-31							0
AF-CCL-5-32							0
AG-CCS-4-33							0
AH-SNS-4-34			X				33
AI-SCS-5-35					X		33
AJ-CCS-5-36					X		33
AK-SNS-5-37			X				33
AL-CNL-5-38	X			X			33
AM-SCL-5-39	X		X				33
AN-SNL-5-40							0

Legend: X International Student

E.10. Team Gender Analysis

TEAM NAME	GENDER						% FEM.
	D1	D2	M1	M2	S1	S2	
D-SCL-1-1	M	M	F	M	M	F	33
H-SNS-1-2	M		M		F		33
F-CNL-1-3	M	F	M	M	M	M	16
B-CCS-1-4	M		M		F		33
I-SCS-1-5	M		M		M		0
E-SNL-1-6	M	F	M	M	F	M	33
C-CCL-1-7	F	M	F	F	M	M	50
A-CNL-2-8	M	M	M	M	M	F	16
G-CNS-1-9	M		M		M		0
J-CNL-3-10	M	M	M	M	M	M	0
K-CCS-2-11	M		M		M		0
L-SCS-2-12	M		M		F		33
M-SNS-2-13	M		M		M		0
N-CNS-2-14	M		M		M		0
O-CNS-3-15	M		M		M		0
P-CCS-3-16	M		M		M		0
Q-SCS-3-17	M		M		M		0
R-SCL-2-18	M	M	M	M	M	M	0
S-SNS-3-19	M		M		M		0
T-CNS-4-20	M		F		M		33
U-CNS-5-21	M		M		M		0
V-CCL-2-22	M	M	M	M	M	M	0
W-SCL-3-23	M	M	M	M	M	F	16
X-CCL-3-24	M	M	M	M	F	M	16
Y-SNL-2-25	F	M	M	M	M	M	16
Z-CCL-4-26	M	M	M	M	M	M	0
AA-CNL-4-27	M	M	M	M	F	M	16
AB-SNL-3-28	M	M	M	M	M	M	0
AC-SCS-4-29	M		M		M		0
AD-SCL-4-30	M	M	M	M	M	M	0
AE-SNL-4-31	M	M	M	M	M	M	0
AF-CCL-5-32	M	M	M	M	F	F	33
AG-CCS-4-33	M		M		M		0
AH-SNS-4-34	M		M		M		0
AI-SCS-5-35	M		F		M		33
AJ-CCS-5-36	M		F		M		33
AK-SNS-5-37	M		M		M		0
AL-CNL-5-38	M	M	F	F	M	M	33
AM-SCL-5-39	M	M	M	M	M	M	0
AN-SNL-5-40	M	F	M	M	M	M	16
TOTALS	2	3	6	2	7	4	

Legend: M Male
F Female

E.11. Team Academic Analysis

TEAM	GRADE POINT AVERAGE						GROUP
NAME	D1	D2	M1	M2	S1	S2	AVE.
D-SCL-1-1	( )	( )	3.8	( )	( )	( )	
H-SNS-1-2	3.8		3.4		3.5		3.5
F-CNL-1-3	3.9	3.72	4.0	( )	2.78	( )	
B-CCS-1-4	( )		3.7		3.9		
I-SCS-1-5	( )		( )		( )		
E-SNL-1-6	2.7	( )	4.0	( )	( )	( )	
C-CCL-1-7	( )	3.4	3.5	( )	( )	( )	
A-CNL-2-8	( )	( )	( )	( )	3.4	3.86	
G-CNS-1-9	3.5		( )		( )		
J-CNL-3-10	0.54	3.04	1.51	( )	2.67	1.89	
K-CCS-2-11	3.3		2.8		1.04		2.38
L-SCS-2-12	( )		3.6		( )		
M-SNS-2-13	3.66		3.25		3.2		3.37
N-CNS-2-14	2.28		2.26		2.4		2.31
O-CNS-3-15	3.3		1.79		( )		
P-CCS-3-16	2.8		1.7		2.5		2.33
Q-SCS-3-17	3.0		3.1		2.1		2.73
R-SCL-2-18	2.45	2.4	3.35	2.2	2.1	2.88	2.56
S-SNS-3-19	2.8		2.83		2.5		2.71
T-CNS-4-20	3.1		3.5		2.14		2.91
U-CNS-5-21	3.17		3.5		2.5		3.06
V-C-2-22	2.0	3.1	3.2	2.8	2.25	2.8	2.69
W-SCL-3-23	3.3	2.0	3.2	2.0	2.6	1.82	2.49
X-CCL-3-24	3.7	3.0	1.9	3.51	( )	2.0	
Y-SNL-2-25	2.0	3.5	2.16	2.74	1.83	2.4	2.44
Z-CCL-4-26	1.86	2.2	1.7	1.95	1.62	( )	
AA-CNL-4-27	2.5	( )	2.2	2.35	3.93	2.75	
AB-SNL-3-28	2.25	3.25	2.5	2.0	3.2	2.5	2.62
AC-SCS-4-29	2.83		( )		3.86		
AD-SCL-4-30	2.26	2.6	3.6	2.4	2.3	2.25	2.57
AE-SNL-4-31	1.9	3.57	2.7	2.7	3.35	2.28	2.75
AF-CCL-5-32	3.2	2.0	2.4	( )	3.7	3.92	
AG-CCS-4-33	2.6		2.01		2.3		2.30
AH-SNS-4-34	2.7		( )		3.6		
AI-SCS-5-35	2.8		3.8		3.7		3.43
AJ-CCS-5-36	( )		( )		( )		
AK-SNS-5-37	( )		3.5		2.0		
AL-CNL-5-38	2.9	3.0	3.0	( )	2.8	2.1	
AM-SCL-5-39	3.4	( )	( )	3.0	2.2	( )	
AN-SNL-5-40	2.7	2.5	2.4	2.7	3.0	2.9	2.70

Legend: ( ) Unavailable

E.12. Videotape Log Form

TEAM NAME	DATE	TAPE NUMBER(S)
D-SCL-1-1	11/13/96	1,2
H-SNS-1-2	11/15/96	3,4
F-CNL-1-3	11/16/96	5,6
B-CCS-1-4	11/17/96	7,8
I-SCS-1-5	11/17/96	9,10
E-SNL-1-6	11/18/96	11,12
C-CCL-1-7	11/19/96	13,14
A-CNL-2-8	11/29/96	15,16
G-CNS-1-9	12/13/97	17,18
J-CNL-3-10	1/13/97	19,20
K-CCS-2-11	1/14/97	21,22
L-SCS-2-12	1/15/97	23,24
M-SNS-2-13	1/16/97	25,26
N-CNS-2-14	1/16/97	27,28
O-CNS-3-15	1/17/97	29,30
P-CCS-3-16	1/17/97	31,32
Q-SCS-3-17	1/18/97	33,34
R-SCL-2-18	1/18/97	35,36
S-SNS-3-19	1/19/97	37,38
T-CNS-4-20	1/19/97	39,40
U-CNS-5-21	1/19/97	41,42
V-CCL-2-22	1/20/97	43,44
W-SCL-3-23	1/21/97	45.46
X-CCL-3-24	1/22/97	47,48
Y-SNL-2-25	1/22/97	49,50
Z-CCL-4-26	1/23/97	51,52
AA-CNL-4-27	1/24/97	53,54
AB-SNL-3-28	1/24/97	55,56
AC-SCS-4-29	1/25/97	57,58
AD-SCL-4-30	1/25/97	59,60
AE-SNL-4-31	1/27/97	61,62
AF-CCL-5-32	1/29/97	63,64
AG-CCS-4-33	1/30/97	65,66
AH-SNS-4-34	1/31/97	67,68
AI-SCS-5-35	2/3/97	69,70
AJ-CCS-5-36	2/7/97	71,72
AK-SNS-5-37	2/9/97	73,74
AL-CNL-5-38	2/9/97	75,76
AM-SCL-5-39	2/9/97	77,78
AN-SNL-5-40	2/11/97	79,80

Appendix F - External Survey

F.1. Addressees

F.1.1. Industry Experts

Department of Defense
Mr. Don Hall
5001 Gunpowder Road
Fairfax, VA 22030
703-830-4586

Dupont Central Research
Dr. Parry M. Norling
Experimental Station 326/306
P.O. Box 80326
Wilmington, DE 19880-0326
norling@a1.esvax.umc.dupont.com

EDS
Mr. James D. Nyfeler
Division Vice President
Manufacturing Group
H3-4C-46
5400 Legacy Drive
Plano, TX 75024

Litton Amecom
Mr. Larry Linton
5115 Calvert Road
College Park, MD 20740-3898
301-454-9232

Lockheed Martin Federal Systems
Mr. Robert McCaig
Technical Director, Navy Systems
9500 Godwin Drive
Manassas, Virginia 20110

Lockheed Martin Federal Systems
Dr. Dinesh Verma
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Manassas, VA 22110
703-367-6888
dinesh.verma@lmco.com

Newport News Shipbuilding
Mr. Kenton Meland
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Newport News, VA 23602
757-380-3844
meland@aol.com

Mr. R. Bruce Pittman
Profit Engineering Technologies
22 S. Santa Cruz Ave. Suite E
Los Gatos, CA 95030
408-354-3680
bpittman@scuacc.san.edu

Rockwell International
Mr. Grant Keller
16009 Nordoff Street
Sepulveda, CA 91843
818-893-3869

Systems Management International
Mr. Jim Brill
General Manager
3125 Hacienda Drive
Pebble Beach, CA 93953
408-372-2473
jbrill@mbay.net

Systems Management International
Dr. Jerry Lake
Chief Scientist
281 S. Pickett St., #401
Alexandria, VA 22304
703-751-7987
lakejg@smisyseng.com

TRW
Ms. Anita Gates
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Redondo Beach, CA 90278
310-813-0399

United Technologies
Ms. Ginny Lentz
411 Silver Lane
East Hartford, CT 06108
860-610-7301
lentzva@utrc.utc.com

United Technologies
Dr. Ralph Wood
MS 129-48
411 Silver Lane
East Hartford, CT 06108
203-727-7331
woodrt@utrc.utc.com

Westinghouse Electronics (former)
Ms. Naomi McAfee
13 Seminole Avenue
Catonsville, MD 21228
410-744-6572
ghnjmcafee@aol.com

F.1.2. Academic Experts

Georgia Tech
Dr. Dan Schrage
Helicopter Design Center
Atlanta, GA 30332
404-894-6257

University of Exeter
Dr. Jezdimir Knezevic
Director, MIRCE Research Center
School of Engineering
North Park Road
Exeter, DEVON EX4 4QF England
011-44-1392-263612

University of Iowa
Dr. Ed Haug
Center for CAD
Iowa City, IA 52242
319-335-5726
haug@ccad.uiowa.edu

University of Maryland
Mr. Michael Pecht
Department of Mechanical Engineering
College Park, MD 20742
301-454-8866

University of Southern California
Dr. Dave Belson
GER 240, University Park
Los Angeles, CA 90089-0193
213-743-1623

University of Virginia
Dr. Susan Carlson
Mechanical Engineering Thornton Hall
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804-924-6221
sec3a@virginia.edu

University of Washington
Dr. Brian W. Mar
Department of Civil Engineering
P.O. Box 352700
Seattle, WA 98195-2700
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bwmar@u.washington.edu

Virginia Tech
Prof. Ben Blanchard
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Blacksburg, VA 24061
540-231-9762
bsblanch@vtvm1.cc.vt.edu

Virginia Tech
Mr. Howard Robins
Northern Virginia Graduate Center
2990 Telestar Court
Falls Church, VA 22042
703-698-6090

Virginia Tech
Dr. Bill Sullivan
302 Whittemore Hall
Blacksburg, VA 24061
540-231-6659
bills@vt.edu

West Virginia University
Dr. Ramana Reddy
886 Chestnut Ridge Road
Morgantown, WV 26506
304-293-7226

F.2. Letter

Date

Address

Dear ___________:

Since returning to Virginia Tech four years ago as President of the Corporate Research Center, I've had the privilege of working on a doctoral degree in Industrial and Systems Engineering. As the former co-chairman of the CALS Industry Steering Group's Concurrent Engineering (CE) group (with Naomi McAfee), I continue to be interested in CE.

At Tech, I have been attempting to simulate concurrent engineering in a laboratory environment while considering other process variables like group size and the use of collaborative computer tools like groupware. Now that the laboratory phase of my research has been completed, I'm interested in your opinion on some of the issues that I have been investigating.

I've enclosed a survey instrument. I would greatly appreciate it if you would complete the survey and return it to me as soon as possible. Graduation in May is just around the corner. Of course, you can't tell from the survey what I've learned since I've had to change the wording to reflect proper survey techniques. I would be delighted to discuss my results with you at your convenience, or you may read my dissertation on the Internet in May.

As a recognized national expert in CE, I welcome any elaboration that you may wish to make on any of the topics suggested by the questions. Of course, anything that you say might be quoted in my dissertation with attribution (or without attribution, if you wish).

Thanks, in advance, for your support of my research.

Sincerely,

Joe W. Meredith

F.3. Survey Questionnaire

RESEARCH SURVEY INSTRUMENT
Joe W. Meredith
February 12, 1997

Definitions:	Large Groups:	Six persons
	Small Groups:	Three persons
	Groupware:	Group Systems by Ventana Corporation
	Concurrent Engineering:	CE and its synonyms like IPPD, simultaneous engineering, etc…

Please circle your answer using the following scale:

SA	A	U	D	SD
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

1. Compared to sequential engineering, concurrent engineering shortens product development times.

SA **A** **U** **D** **SD**

2. Compared to sequential engineering, concurrent engineering increases product quality.

SA **A** **U** **D** **SD**

3. Compared to sequential engineering, concurrent engineering lowers the cost of production.

SA **A** **U** **D** **SD**

4. Compared to sequential engineering, concurrent engineering lowers the life-cycle cost of a product.

SA **A** **U** **D** **SD**

5. The use of multidisciplinary or cross-functional teams is the major tenet of concurrent engineering.

SA **A** **U** **D** **SD**

6. Compared to small groups, large groups do produce enough benefits to offset their costs for creative engineering design.

SA **A** **U** **D** **SD**

7. Groups that use groupware are more satisfied with the group decision process than groups that use techniques like nominal group technique.

SA **A** **U** **D** **SD**

8. Groupware is more effective for large groups than small groups.

SA	**A**	**U**	**D**	**SD**

9. Large groups are more likely to generate more ideas per member than small groups.

SA	**A**	**U**	**D**	**SD**

10. Groups using concurrent engineering are more likely to be satisfied than sequential engineering groups.

SA	**A**	**U**	**D**	**SD**

11. Groups with good group dynamics will outperform groups with poor group dynamics.

SA	**A**	**U**	**D**	**SD**

12. More time and resources committed to conceptual design results in the expenditure of less resources in detail design.

SA	**A**	**U**	**D**	**SD**

13. Please elaborate below on any of the issues suggested by the questions:

____

____

____

____

____

____

____

____

____

____

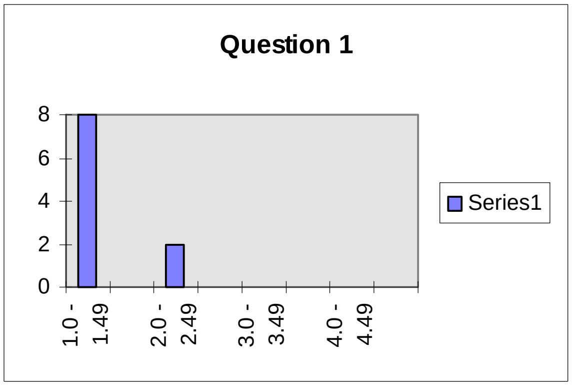
(you may additional pages, if necessary)

14. You may quote me. I am: ____

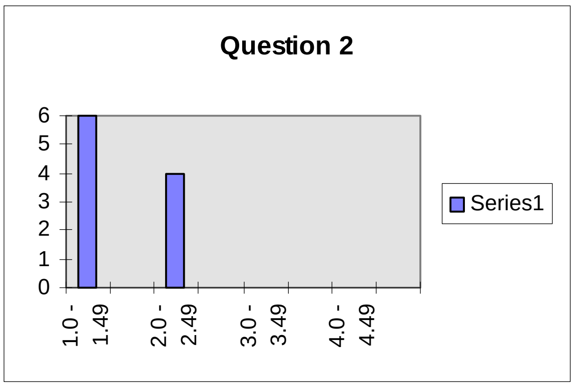
15. I have ______________ years of experience related to the engineering design process.

F.4. External Survey Results

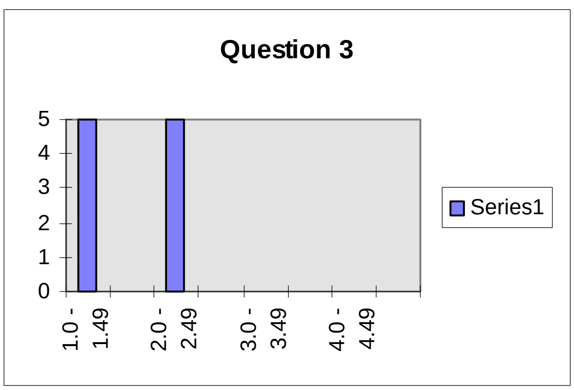
					EXTERNAL SURVEY RESULTS								
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**YRS**
Blanchard	1	1	1	1	1	4	3	4	4	1	1	3	44
Knezevic	2	2	2	2	1	2	3	3	3	2	2	1	10
Lake	2	2	2	2	5	2	3	3	3	2	1	2	12
Lentz	1	1	1	1	1	1	3	3	4	1	1	3	30
Linton	1	1	1	1	1	2	2	1	1	1	1	1	25
McAfee	1	1	1	1	2	2	3	3	1	2	1	1	40
Pecht	1	1	2	1	2	2	4	3	2	2	1	1	14
Robins	1	2	1	1	1	2	3	3	4	2	1	1	27
Skalak	1	1	2	2	1	3	3	2	2	3	1	1	13
Verma	1	2	2	1	2	4	3	3	4	2	1	2	5
MEAN	1.2	1.4	1.5	1.3	1.7	2.4	3	2.8	2.8	1.8	1.1	1.6	22
STDDEV	0.422	0.516	0.527	0.483	1.252	0.966	0.471	0.789	1.229	0.632	0.316	0.843	13.266



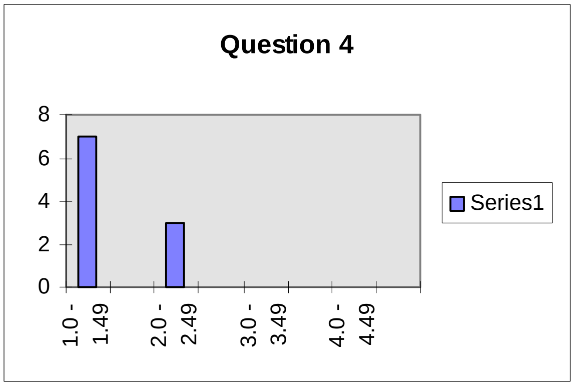
CE shortens product development times.



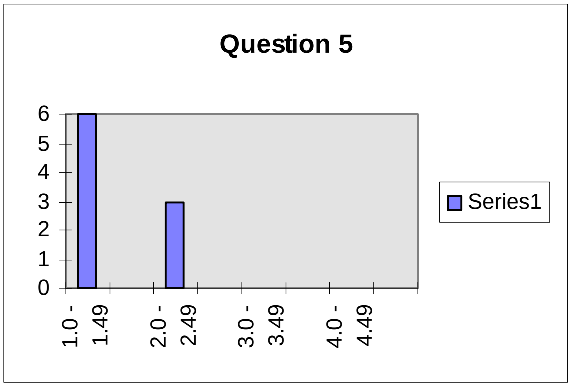
CE increases product quality.



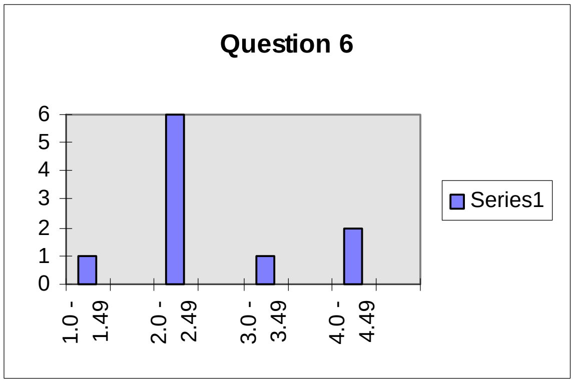
CE lowers the cost of production.



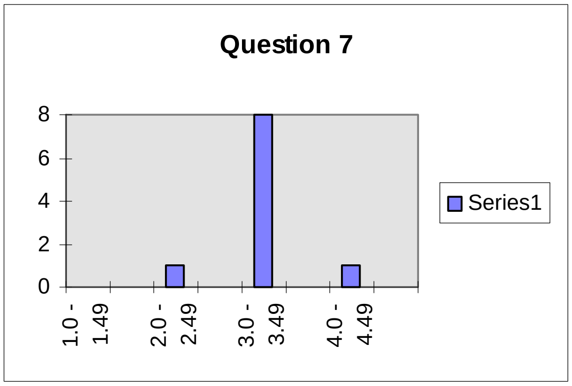
CE lowers the life-cycle cost of a product.



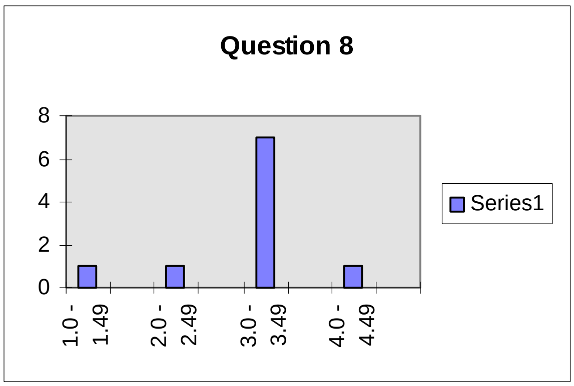
Multidisciplinary teams are the major tenet of CE.



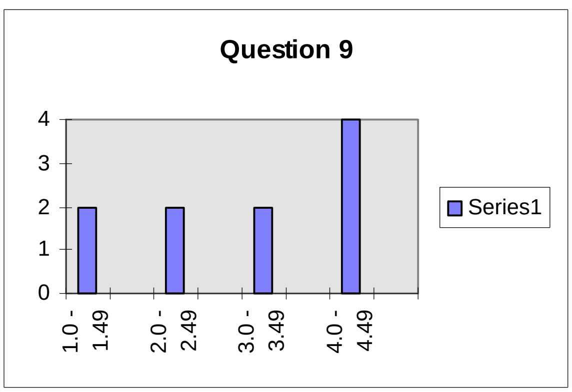
The benefits of large groups offset their costs.



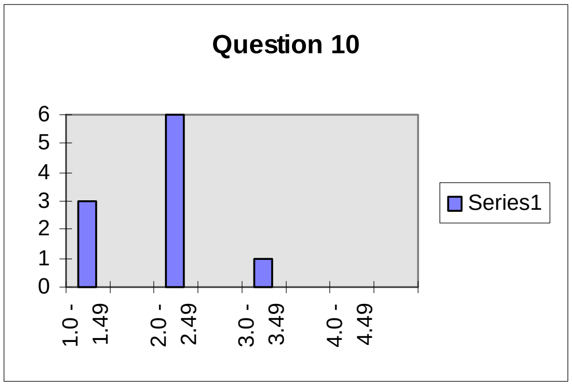
Teams that use groupware are more satisfied.



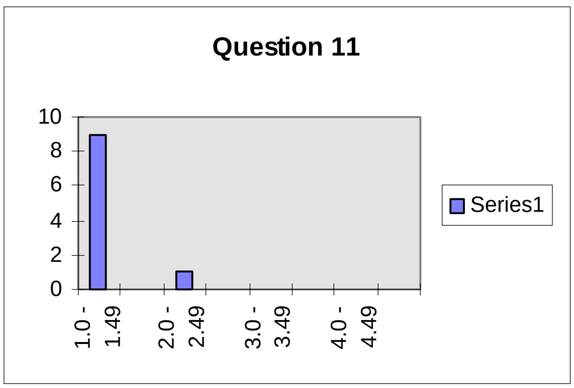
Groupware is more effective for large groups.



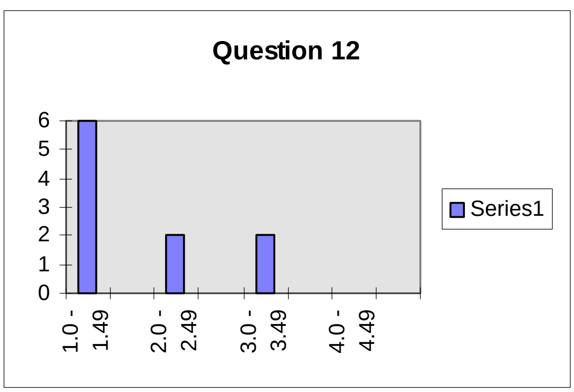
Large groups generate more ideas per member.



Groups using CE will be more satisfied.



Groups with good group dynamics perform the best.



Resources committed to conceptual design result in less resources in detail design.

Vita

Joe W. Meredith, Ph. D.

EDUCATION

Ph.D., Industrial and Systems Engineering, Management Systems Engineering emphasis, Virginia Tech, Blacksburg, VA, May 1997.
Dissertation Title: Empirical Investigation of Sociotechnical Issues in Engineering Design.
Research Advisor: Dr. Brian M. Kleiner

M.S., Aeronautics, Astronautics, and Engineering Sciences, Purdue University, West Lafayette, IN, August 1970.

B.S., Aerospace Engineering, Virginia Tech, Blacksburg, VA, June 1969, graduated Magna Cum Laude.

Program Management Course, Defense Systems Management College, Fort Belvoir, VA, May 1983.

PROFESSIONAL EXPERIENCE

President, Virginia Tech Corporate Research Center, Blacksburg, VA; February 1993 - present.
Manage university-related research park consisting of nine buildings, 258,000 square feet, 125 acres, that house 65 companies employing over 1000 people. Responsible for increasing sponsored research, and technology transfer from the university.

President, Advanced Engineering Processes, Poquoson, VA; March 1992 - February 1993.
Consulted and developed training materials for major corporations like IBM on concurrent engineering design methodologies.

Manager, Integrated Logistics Support, Newport News Shipbuilding, Newport News, VA; 1990 - 1992.
Managed 400 person ILS division that provided maintenance planning, supply support, training, reliability, safety, and technical documentation for nuclear aircraft carrier and submarine programs.

Manager, Washington Office, Newport News Shipbuilding, Arlington, VA; 1987 - 1990.
Managed 50 person engineering office that provided on-site support to the Naval Sea Systems Command.

Manager, Marketing, Newport News Shipbuilding, Newport News, VA; 1981 - 1987.
Proposal manager for over $1 billion in proposals relating to CG51, DDG51, and Iowa Reactivation programs.

Manager, Production Computer Systems, Newport News Shipbuilding, Newport News, VA; 1977 - 1981.
Managed 75 programmer/analysts that developed major computer applications for inventory control, production scheduling and control, and design support.

Various Positions, Newport News Shipbuilding, Newport News, VA; 1970 - 1977.
Conducted research as a research engineer, wrote major computer applications as a computer systems engineer, managed engineers and programmer/analysts as an engineering computer systems supervisor.

OTHER RESPONSIBILITIES
Board of Directors of Virginia Tech Intellectual Properties, Inc.;
Advisory Board of the Virginia Tech Business/Technology Center;
Treasurer of the Montgomery Regional Economic Development Commission;
New Century Council's Technology Committee;
Board of Directors of the New River Valley Economic Development Alliance.