**Massachusetts Institute of Technology**
**Department of Aeronautics And Astronautics**

# 16.621 / 16.622

# EXPERIMENTAL PROJECTS LAB I / II SUBJECT SYLLABUS

# Fall 2003

**YOU are responsible for reading and understanding this document**

## Table of Contents

## Personnel and Contact Information

### Course Faculty

Prof. Edward M. Greitzer

Prof. John Deyst

### Writing Program Faculty

Jennifer Craig

### Laboratory Hours

Monday - Friday, 9:00 -12:00, 1:00 - 4:30

Please try to avoid showing up just before closing time, especially when you need lab personnel help. If these hours are insufficient, please consult Laboratory Staff.

# Introduction to 16.62x

## 16.621 and 16.622

16.62x is part of the capstone sequence in the Department of Aeronautics and Astronautics. 16.622 is used to fill the Institute Laboratory requirements. Many students use the 16.621 design proposal or the 16.622 final report to fulfill the Institute Phase II writing requirements. Figure 1 shows the general scope of the 16.621 / 16.622 sequence. During the two terms, you will Conceive, Design, Implement, and Operate an experimental project of your choosing. Finally you will report your findings in a format suitable for submission to a student conference.

| | |
|---|---|
| **Preliminary**<br>Select Partner<br>Select Project and Advisor | **16.621** |
| **Conceive**<br>Statement of Project<br>Hypothesis, Objective(s), Success Criteria<br>Literature Review<br>Experimental Definition | |
| **Design**<br>Measurement Methods and Systems<br>Data Reduction Procedures<br>Detailed Experiment Design<br>Equipment Specification<br>Apparatus/Software Design<br>Project Planning | |
| **Report**<br>Oral/Written Project Proposal | |

| | |
|---|---|
| **Implement**<br>Construct Apparatus/Write Software<br>Calibrate<br>Take Preliminary Data | **16.622** |
| **Operate**<br>Collect and Reduce Data | |
| **Report**<br>Analyze Data<br>Oral/Written Conference Presentation | |

**Figure 1: Overview of 16.621 and 16.622.**

During the first two weeks of **16.621**, you will select a partner, project, and advisor.

During the rest of the semester, you'll develop that design project to the level of specificity that makes it possible for you to implement the design in 16.622. As you do this, you're learning and practicing a process by which all "good ideas" become successful design proposals. The semester will naturally divide into two major blocks. Up to the Oral Proposals (week 9), you will be focusing on the conceptual design of your project - the Conceive phase. Material introduced in the Tuesday and Thursday classes will be directly relevant to this portion of the proposal. After the Oral Proposals, you will turn to the Design phase of the project. Class time will be replaced by hands-on shop training, Solid Works training, and other detailed design activity. In this phase, you will be working closely with the Laboratory Staff. The expectation is that your design will be ready for implementation at the end of 16.621.

You'll communicate the results of your work in four deliverables: Version I, Version II, the oral presentation of your proposal and Version III. (Please see Appendix B for a complete description.) Each deliverable expands and revises your original concept as you focus your project and as your thinking becomes more precise and more specific.

During **16.622**, the implementation of your experiment begins immediately as you fabricate and assemble your experimental apparatus and/or software. Early in the term, you will deliver an oral progress report to the course faculty and staff. By roughly halfway through the term, you should plan to be in the operation phase, actively collecting and analyzing data. The project culminates with a final oral presentation and written report at the level acceptable by an AIAA student conference. The 16.622 milestones are listed in the Course calendar.

## Phase II Writing Requirement

For students who entered MIT prior to Summer 2001, the final 16.621 project proposal or a solely authored 16.622 final report can be used to satisfy Phase II of the Institute Writing Requirement. All documents will be considered but do not automatically satisfy the Phase II requirement. To be considered for Phase II, you must receive a grade of B- or better on the 16.621 project proposal or on a 16.622 solely authored report, and you must bring the marked-up graded copy to the Course 16 Undergraduate Office.

***Last term seniors who have not satisfied phase II should consult the writing program instructor immediately.***

## Communication Requirement

Students who entered MIT after the summer of 2001 are under the Communication Requirement. As one of the subjects which can be used in the four subject sequence needed to satisfy this requirement, 16.622 is designated as a CI-M subject.

## The Institute Laboratory Requirement and 16.62x

MIT has an Institute Laboratory Requirement that, as stated in the MIT Bulletin, ensures each student is offered "an opportunity to set up and carry out experiments dealing with phenomena of the natural world." The student is expected to "play a substantial role in selecting the design of the experiment, selecting the measurement technique, and determining the procedure to be used for validation of the data."

An explicit part of the description of the laboratory requirement is the formulation and testing of a hypothesis[1] (made through comparison with experimental[2] results. This implies two key elements in the 16.62x cycle.

> Early in the process, there should be a clear description, and an understanding, of the hypothesis; a concept of how to assess its correctness; and a notion of how one would be able to declare the success of this assessment.
> The design and execution of the experiment should always focus on how the information obtained will address the test of the hypothesis.

## Learning Objectives for 16.621/16.622

The goal of 16.621/16.622 is to enable you to master the relevant methods, processes, and techniques necessary for conceiving, designing, implementing, operating, and documenting an experimental project aimed at the investigation of a hypothesis. Inherent in this goal is the development of your communication skills so you can convey technical contributions to other professionals in the field through oral and written reports. Working as an effective member of a team is also an important aspect of the 16.62x experience.

The high-level subject learning objectives are listed below, along with the measurable outcomes that support these objectives. More specifics are listed in Appendix A.

## Learning Objectives

At the end of the 16.621/16.622 cycle, you will be able to:

> Formulate the overall objectives and success criteria for an experimental study to assess a hypothesis about phenomena of the natural world.
>
> Develop as a two-person team the strategy and tactics for the design of an experiment and for data analysis procedures to achieve these objectives, including detailed description of the necessary technical tasks.

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[1] "Hypothesis: (1) A tentative explanation that accounts for facts and can be tested by further investigation; **a theory**, (2) Something taken to be true for the purpose of argument or investigation; **an assumption**." [from *American Heritage Dictionary*, 3rd Edition].

[2] "Experiment: A test under controlled conditions that is made to demonstrate a known truth, examine the validity of a hypothesis, or determine the efficacy of something previously untried." [from *American Heritage Dictionary*, 3rd Edition].

Implement, as a two-person team, a detailed design for an experiment and for data analysis procedures necessary to achieve the objectives defined above.

Execute, as a two-person team, an experiment which will successfully assess a defined hypothesis.

Effectively communicate, orally and in writing, the results of the project design process, and subsequently the key aspects of the overall project (from concept to end goal).

## Measurable Outcomes

Development of experiment hypothesis, objective and success criteria (16.621)

Critical assessment of previous work and its relevance and relation to your project (16.621)

Conceptual design of the experiment and data analysis process (16.621)

Definition of the experimental variables and the test matrices (16.621)

Analysis of the experimental errors in the context of their impact on the project goals (16.621 and 16.622)

Development and delivery of an oral presentation describing the key aspects of the proposed project from concept to detailed design and planning(16.621)

Development and delivery of a written document describing the proposed project from concept to end results(16.621)

Development and delivery of an oral presentation that summarizes the status of project and allows a clear view of the progress to date and an appropriate assessment of the route to completion (16.622)

Construction of an experimental apparatus or development of an experimental process aimed at the assessment of a hypothesis.

Development and delivery of an oral presentation suitable for a professional audience, describing the key aspects of the project from concept to end results (16.622)

Development and delivery of a written document suitable for a professional audience, describing the project from concept to end results (16.622)

## Demonstration of Communication Skills

Although the communication aspects of 16.621 and 16.622 are included in the learning objectives and measurable outcomes, they are important enough that we list below the communication skills you will demonstrate during the course. This includes:

Ability to select a communications strategy (choice of what to communicate)

Ability to implement a communications strategy (implementation of the above choice) including selection of graphical techniques

Ability to orally communicate technical and project management material

Ability to effectively communicate with a team partner and with an extended team of stakeholders.

## Quantitative Assessment of Student Learning

Assessment of your learning follows from the measurable objectives and takes several different forms:

professional level laboratory notebooks assessed on technical content and

written and oral assignments that exhibit your technical and your communication skills.

Your learning and performance will be assessed by the 16.62x faculty and technical staff and by your project advisor.

## 16.621 Assessment

The final grade in 16.621 will be allocated as listed in Table I.

**Table I: 16.621 Grade Allocation**

| Assessment Tool | % Final Grade |
|---|---|
| 3 Notebook Checks | 9% |
| Version I | 10% |
| Version I revised and Version II | 10% |
| Oral Project Proposal (I,II) | 20% |
| Advisor's Grade - I | 10% |
| Final Written Proposal | 20% |
| Advisor's Grade - II | 10% |
| Technical Staff Grade | 10% |
| Subject Evaluation | 1% |

A detailed description of the 16.621 deliverables is listed in Appendix B.

## 16.622 Assessment

The final grade in 16.622 will be allocated as listed in Table II.

**Table II: Grade Allocation**

| Assessment Tool | % Final Grade |
|---|---|
| 3 Notebook Checks | 9% |
| Oral Progress Report | 15% |
| Final Oral Presentation | 20% |
| Final Written Report | 25% |
| Advisor's Grade | 20% |
| Technical Staff Grade | 10% |
| Subject Evaluation | 1% |

A detailed description of the 16.622 deliverables is listed in Appendix C.

# Roles and Responsibilities

## Student's Role

First and foremost, this is your project. You choose the topic and advisor. Your responsibility is to define an experimental problem, develop a hypothesis, create objective statement(s) and success criteria consistent with the definition of the problem, identify experimental goals, design and construct the apparatus needed to perform the research, conduct the appropriate testing, evaluate the results, and propose relevant conclusions. The research results determine the degree to which your conclusions are warranted, and ultimately determine the success of your undertaking. To persuade others of this success, it is your responsibility to present your results and conclusions in oral and written reports.

***It cannot be emphasized too strongly that your course grade depends on the proper execution of the experimental process so as to assess your hypothesis. It does not depend on showing that the hypothesis is true.***

A number of people will contribute to the success of your experiment. It is a good idea to identify these "stakeholders" and develop effective working relationships with them. Your "core" team includes your partner and advisor. Your "extended" team would include the course faculty, technical staff, writing program faculty, undergraduate TAs, and suppliers of parts, components or services needed for your experiment. Course faculty will help with some tips about working with such a large number of stakeholders and faculty will be available to assist you in this respect.

This might be your only exposure to truly independent work while a student at MIT. In addition to learning, your goals should include having fun and being able to look positively on this experience.

## Project Advisor's Role

Your project advisor is responsible for guiding you in designing and executing your project and in interpreting your results. *Arrange to meet with your project advisor at a fixed time each week.* Remember that many faculty members travel often so it is essential that you make appointments to meet well in advance. If you absolutely cannot meet with your advisor, make an appointment with one of the course faculty to review your progress.

## Course Faculty's Role

The course faculty are responsible for the structuring of the subject and the development of the learning objectives, subject content, and assessment tools. The course faculty will lead all class and team meetings and grade all written and oral material. The course faculty, together with input from the 16.62x staff and Writing Program Instructor, are responsible for assessing your progress towards meeting the class learning objectives.

## Writing Program Instructor's Role

The writing program instructor is responsible for organizing and running the communications content of 16.62x and for evaluating all Phase II papers. She contributes evaluations and commentary on oral and written assignments submitted for 16.62x and is available to all students for individual or team consultations. In addition, she teams with the course faculty for the development of all aspects of the subject, with a particular focus on communications aspects.

## Technical Staff's Role

The technical staff will assist you with the use of laboratory and shop equipment, ordering materials, and the solution of technical problems. They are a very knowledgeable and valuable resource. All past 16.62x classes have found them enormously helpful. Use them!

## Teaching Assistants' Role

16.62x has recent 16.622 alumni serving as teaching assistants for the course. The TAs are available to help you plan and execute your project. Having recently been "in the trenches," the TAs will be uniquely able to assist you with a variety of issues from understanding the course objectives through directing you to the appropriate laboratory staff member to solve a difficult instrumentation problem. The TAs will also grade your notebooks and will provide a student viewpoint in all 16.62x staff meetings.

# General Guidelines

## Announcements

The faculty and staff will transmit essential course information by email. This includes changes in the schedule and sign-up lists. For 16.622 students, this is your primary source of information since there are only a few class meetings.

## Late Submission of Work

All written material, including notebooks, is required to be submitted at the time and location listed on the course calendar. Any written material submitted after this time will be graded as late with a penalty of 10% per day of the maximum possible grade. Permission to submit written material late without penalty may only be obtained from the course faculty if there is a valid reason. Except in extreme cases, this permission must be obtained at least two days prior to the due date.

You will be using computers and software for preparation of professional-level work. Remember, however, that computer-related disasters are not considered excuses for missing deadlines. Back-up your files![3]

## Plagiarism

Plagiarism is defined as the act of presenting someone else's words, ideas, illustrations, or other intellectual property as your own. All use of another person's, company's, or institution's words, ideas, illustrations, or intellectual property must be properly referenced and acknowledged according to AIAA standards. If in doubt about whether to reference or not, double-check with a course faculty member. Also, be aware that a student who knowingly allows his or her work to be copied is also guilty of plagiarism. Plagiarism is a serious transgression and will result in penalties.

## Division of Work in Project Teams

**Working together:** Partners are expected to work together in defining the problem, exploring design options, constructing the apparatus, taking data, and discussing other aspects of their project. Because of the team nature of the course, a few clarifications relating to academic honesty are provided below.

Oral progress reports and oral presentations are regarded as a combined effort and normally are graded as such. Partners should participate equally in both the presentation and the question-and-answer session.

[3] The course faculty have already heard many imaginative reasons for loss of data; back up so you don't add to this repository of plaintive stories.

Figures, tables of data, graphs, and typeset equations used in oral and written deliverables can, and likely should, be prepared jointly between team members.

**Working separately:** Notebooks must be kept separately. In the execution of an experiment, one partner may take data while the other operates the experiment. In that case, data should be transferred from one notebook to another by hand or photocopy. In general, however, each notebook should be an individual effort, documenting the project's progress. See Appendix D for further guidelines on laboratory notebooks.

Written material reflects the degree of understanding which you have gained from the work and your capacity to convey the results to others. Everyone is strongly encouraged to discuss organization, results, conclusions, etc. with their partner, faculty advisor, and 16.62x staff members. However, the 16.621 project proposals and any solely authored 16.622 final written reports must be individual efforts. Duplication or direct paraphrasing of text is not allowed and is considered to constitute plagiarism. **An exception to this is that the Hypothesis, Objective, and Success Criteria statements must be the same for all members of a team.**

## Budget Planning

Course 16 allocates a maximum of $500 to each 16.62X project for materials and purchased services. Teams develop a draft project that is included in Version II; a final budget is included in the Version III project proposal. The budget should include all materials or services which require the expenditure of funds during 16.622, plus a 10% "management reserve" for unexpected changes. If the proposed project budget in 16.621 exceeds the Department allocation, the project team should meet with Laboratory Staff between the Version II and III proposals to either develop an approved plan for funding or to revise the scope of the project. For the former, additional sources of funds could come from the Department, the project advisor, or other MIT programs.

Project teams are expected to execute their 16.622 projects within the Version III approved budget. If costs should increase beyond this level, the team must meet immediately with Laboratory Staff to develop a revised plan which could include one or more of the following elements; increased funding, alternative strategies for equipment or services, reduced project scope, or project termination.

## Pacing of the Course

While this course is based on independent project work, doing all of the work in the final weeks of the semester is simply not acceptable. (It is also an observational fact that doing the course in this manner is generally not conducive to a good final product.) You are learning a process as well as producing a final product and steady progress is expected throughout the semester. The 16.62x staff reviews the progress of each team in its weekly Wednesday morning staff meeting, using a Green/Yellow/Red status ranking:

**Green:** Project proceeding smoothly and on schedule

**Yellow:** Some concern about progress or technical difficulties, but expect that team can resolve issues and successfully complete project.

**Red:** Project is behind schedule or having difficulty. Issues need to be addressed and resolved, or project may not be completed successfully.

Those teams with Red status ranking will be so advised. At all times, the 16.62x staff is available to assist teams to succeed in their project planning and execution.

## Audience and Level of Technical Detail for Deliverables

You may assume that the audience is technically proficient and has a general knowledge of aeronautical and astronautical engineering. However, you must define or explain any specialized terms, concepts, or testing methods which are involved with your project.

It is **your** responsibility to make sure that oral presentations and written reports are presented in such a way that any department faculty or senior research staff, without prior knowledge of the project, can understand them. While various written and oral presentations may each have a different focus, *each must be able to stand alone*. That is, the audience's understanding of the material should not depend on whether they have listened to oral presentations or read previous reports. Thus, it is important for every technical report or presentation to **clearly and concisely articulate the motivation for the work, the hypothesis, the objectives, the success goals, and the experimental approach.**

## Written Report Style Guidelines

Technical and professional writing follows certain stylistic conventions. Professional Societies (AIAA, ASME, IEEE, etc.) and organizations (NASA, FAA, etc,) have style guidelines for their publications. A 16.62x Style Guide is available online and in hardcopy. It is representative of aerospace professional and organization style guides. You are expected to use the 16.62x Style Guide in your 16.62x deliverables. Please consult the Writing Program Faculty if you have questions.

## Presentations and Publications

The final written and oral deliverables in 16.622 may be suitable for submission to an AIAA student conference or another professional society conference or journal appropriate for the subject matter. Many 16.622 projects result in findings of interest to the professional community and in the past have received recognition and awards external to MIT. An annual AIAA Northeast Regional Student Conference provides an excellent opportunity to present 16.622 results. Presentations are judged with the three top papers receiving cash awards, and the top presentation invited to participate in the annual AIAA Aerospace Sciences Meeting in Reno, NV each January. For more information about submitting a paper to this competition, see the department AIAA faculty advisor. Also ask your project advisor about suitable venues for presenting or publishing your final results.

# Appendix A: 16.621/16.622 Learning Objectives and the CDIO Curriculum

Over the past few years, the Aero/Astro department has conducted a multi-step program to identify the knowledge, skills, and abilities that are the goals of an undergraduate engineering education and to define where in our curriculum specific items would be taught. The identification process resulted in the CDIO Syllabus[4] which contains a detailed list of the different knowledge, skills, and attributes, plus the expected level of proficiency in each. (In spite of this being MIT, in three years it is not realistic to expect students to become the best in the world at EVERYTHING.) During the past three years the department has focused on the design of the curriculum to provide the desired skills. This latter exercise feeds into the learning objectives of 16.621/622 that support a specific sub-set of the CDIO objectives out of the many contained in the Syllabus. To show the connection, we provide another level of explanation concerning the learning objectives, framed in terms of the CDIO Syllabus, where the numbers below refer to the numbering in the CDIO Syllabus. The general areas at which 16.621/622 is targeted are: 2.2 Experimentation and Knowledge Discovery, 3.1 Teamwork, and 3.2 Communication.

**Learning Objective:** Formulate the overall objectives and success criteria for an experimental study to assess a hypothesis about phenomena of the natural world.

### 2.2.1 Hypothesis Formulation

Ability to select critical questions to be examined, formulate hypotheses to be tested, discuss controls and control groups.

**Learning Objective:** Develop as a two-person team the strategy and tactics for the design of an experiment and for data analysis procedures to achieve these objectives, including detailed description of the necessary technical tasks.

### 2.2.2 Survey of Print and Electronic Literature

Ability to choose the literature search strategy, demonstrate information search and identification using library tools, demonstrate sorting and classifying the primary information, including the quality and reliability of the information, identify the essential and innovations contained in the information, identify research questions that are unanswered, list citations to references.

### 2.2.3 Experimental Inquiry

Ability to formulate the experimental concept, strategy, and tactics including development of test protocols and selection of experimental procedures and data analysis methodology, (if applicable) discussion of the precautions when humans are used in experiments.

[4] "The CDIO Syllabus can be found online at http://www.cdio.org/

**Learning Objective:** Implement as a two-person team a detailed design for an experiment and for data analysis procedures necessary to achieve the objectives defined above.

**Learning Objective:** Execute, as a two-person team, an experiment which will successfully assess and defend hypothesis.

### 2.2.3 Experimental Inquiry

Ability to execute experiment construction, test protocols and experimental procedures, experimental measurements, analyze and report experimental data, (if applicable) compare experimental data versus available models.

### 2.2.4 Hypothesis Test and Defense

Ability to discuss the limitation of data employed, (if applicable) discuss the statistical validity of data, prepare conclusions, supported by data, needs, and values, appraise possible improvements in knowledge discovery, and finally, use the data in a logically consistent and defensible manner to assess the degree to which the hypothesis is valid.

### 3.1.2 Team Operation

Ability to choose goals and agenda as a two-person team, apply ground rules for work allocation and integration, practice effective communication, conduct the integrated planning, scheduling and execution of a project, and even, in some cases, practice conflict negotiation and resolution to achieve the goal of making the whole (team) greater than the sum of the parts (individuals).

**Learning Objective:** Effectively communicate orally and in writing the results of the project design process, and subsequently the key aspects of the overall project (from concept to end goal).

### 3.2.1 Communication Strategy

Ability to: analyze the communication situation, choose communications objectives, analyze the needs and character of the audience, and select the content and organization.

### 3.2.2 Communication Structure

Ability to: construct logical and persuasive arguments, construct the appropriate structure and relationship amongst ideas, choose relevant, credible, accurate supporting evidence, practice conciseness, crispness, precision, and clarity of language.

### 3.2.3 Written Communication

Ability to demonstrate writing with coherence and flow in a technical document.

### 3.2.5 Graphical Communication

Ability to: demonstrate construction of tables, graphs, and charts that convey information in a way that augments written text, interpret formal technical drawings and renderings.

### 3.2.6 Oral Presentation And Interpersonal Communication

Ability to: prepare and deliver presentations and supporting media with appropriate language, style, timing, and flow, demonstrate answering questions effectively.

# Appendix B: 16.621 Deliverables and Milestones

## Notebooks

Details of Notebook use and grading are provided in Appendix D: Laboratory Notebooks.

**Notebook Milestones**

| | |
|---|---|
| September 30, 4 PM | Notebooks due |
| October 23, 4 PM | Notebooks due |
| November 25, 4 PM | Notebooks due |

**Milestones for Versions I, II, III and the oral presentation (descriptions follow)**

| | |
|---|---|
| September 25, 1PM | Written: Version I |
| October 7, 2:15-5:30PM | Team meeting for feedback on Version I |
| October 21, 1 PM | Written: Revised Version I, Version II |
| October 30, 1-6PM | Oral: Revised Version I, Version II<br>Feedback on Versions I, II |
| December 2, 1-5:30PM | Team meeting |
| December 8, 1 PM | Written: Project Proposal (Versions I, II, III) |

## Project Selection

This assignment is the first step in 16.62x. You will select your partner, advisor and project topic.

**Milestones**

| | |
|---|---|
| September 8, 4 PM | Submit partner's names |
| September 10, 4 PM | Advisors may commit to projects |
| September 15, 4 PM | Submit project and advisor selection |

## Process of Choosing Project and Partner

During the first class, the course faculty will talk about selecting a partner and identify those students who have not selected a partner. If you are a student without a 16.621 partner, you will have an opportunity to talk to potential partners. If there are an odd number of students taking 16.621, a team of 3 will be formed.

Also in the first day of class, 16.621 students are given a booklet of abstracts of projects that have been suggested by the faculty. A week is allotted for project exploration. You and your partner should use this time to meet with faculty members to learn more about the various

projects. Following the exploration time, you should seek a commitment from a faculty advisor to allow you to work on a particular project.

You are also encouraged to pursue your own ideas for a project during the exploration period. If you wish to take this approach, discuss your ideas with the course faculty, who may recommend prospective faculty advisors. Students who pursue this option will need to work with their advisor to submit a brief 150-200 word, well thought out proposal by the project selection deadline, September 15. This document should include the following:

Project title

Hypothesis - what is the (your) idea behind the project?

Motivation - why this work is relevant to the technical community

Objective and secondary objectives - a short crisp candidate statement(s) to serve as a starting point to define a project to test a hypothesis or theory

Technical approach - a rough idea of type of measurements, equipment to build, software to write, facilities to use, etc.

Refer to the project booklet for examples.

Be sure to e-mail the following information to the course staff by the selection deadline listed above (one e-mail per group):

Your name and e-mail

Your partner's name and e-mail

A short project title (3-5 words preferred). This title is used only for the staff's recognition of the project. Your future documents do not need to use the same title.

Your advisor's name.

## Team meetings

Former 62x students have indicated that team meetings where faculty, advisor, technical staff, and communication instructor are present are most useful. In order to make these short meetings most productive, it is recommended that you and your partner prepare to describe your past and current work and to pose necessary questions.

Sign up sheets for the October 7 team meeting will be posted on the machine shop door the week of September 15. The other two meetings will be scheduled during the October 7 meeting. **Be sure you and your advisor bring your semester calendars with you to the first team meeting.**

The meetings will take place:

October 7
October 30 (in the Q and A after your oral presentation)
December 2

The final team meeting on December 2 is intended to assure that your design is near completion and any outstanding issues are addressed in time to include in your final Project Proposal.

## Version I

The final deliverable in 16.621 is the project proposal, and students will approach this goal by writing and presenting their project in several iterations. Version I is the first of those iterations.

Version I is a written report that gives the background and significance of the project, states the hypothesis, objective and success criteria, and provides a short overview of your experiment. We expect this deliverable to follow the guidelines in the style guide provided.

The 62x faculty will read and grade Version I and return it to the student with feedback. The student's advisor will read it, too. This document will contain the nucleus of the project, but future iterations should reflect the changes in student thinking and learning as the project progresses.

## Version II

Version II is a written report that begins with a revision of Version I and an expansion that includes a literature review (with appropriate citations), a conceptual definition of the experiment and how the team plans to collect and measure data, a description of error analysis for the project, and a draft budget estimate.

Again, the 62x faculty will read and grade Version II and return it with feedback. This feedback will then be incorporated into the oral presentation of the project.

## Oral Presentation

In the oral presentation of the project, each team will present its work to the 62x community for the first time. Each team will have 13 minutes to present the project, and this will be followed by a 15 question and answer session with the 62x staff, the advisor, and fellow students. Action items will be recorded and sent to the teams for future action.

Time limits are strictly followed; speakers will not be permitted to continue beyond the 13 minute limit. For this reason, it is important that teams practice, and practice opportunities will be made available.

The oral presentation should be done in a manner consistent with professional presentations. Students are required to attend the presentations of three other teams; a portion of the grade depends on this attendance. If, for some reason, a student is not able to do this, s/he should talk to the course faculty.

Please bring 4 black and white photocopies of your presentation with 4-6 slides printed per page.

Clearly, at this stage in the process, the fine details of the project are not clear nor can you cover them all in 13 minutes. However, the presentation should give the mixed audience the context and significance of the project, describe the HOS, show the team's understanding of the issues involved, describe its approach in such detail that the staff can offer constructive criticism. The scope of the material in the oral presentation is that covered by the Version II written deliverable.

## Version III: Complete Project Proposal

The major deliverable for 16.621 is Version III, a detailed project proposal, typical in form and content of a proposal in a professional setting that would be submitted to management or a potential sponsor for funding authorization.

Version III includes the revised Version I and Version II sections and materials developed for the oral presentation. However, it expands to cover the detailed technical plans and drawings or pseudo code, the specifications, the management plans, a final budget estimate, and all necessary summaries, acknowledgements and appendices that complete this kind of document.

The end objective of the project proposal is to have a clear project design that is suitable for implementation at the start of 16.622. The course faculty will evaluate the final submission against this objective. **If further work is needed before the team is ready to start 16.622, students may receive an Incomplete in 16.621, together with specific deficiencies that need to be remedied.**

## Outline for 16.621 Design Proposal

The following outline is representative of a typical 16.621 project proposal. You may need to adapt the outline for your specific project, but the major elements in each Version are typically expected. Roman numerals indicate Version numbers. As you'll see, the sections you developed in Version I, Version II and the oral presentation are reflected in the final design proposal although they may have been revised and/or reorganized.

Cover Page (See last page of the Syllabus) - Versions I, II, III

Executive Summary (not more than 1 page) - Version III

Table of Contents - Version III

List of Figures - Version III

Introduction - Version I
- Background and significance of the project
- Brief overview of previous work
- Conceptual overview of experiment

Hypothesis, Objective and Success Criteria (clear and concise, 1-2 paragraphs, maximum.) - Version I

Literature Review (with appropriate references; please consult style guide) - Version II
- For each study, discuss as appropriate:
  - Theoretical or experimental approach
  - Major findings
  - Limitations or shortcomings of study
- Summarize the previous work and why the additional study you propose will add value to the body of knowledge of this topical area.

Technical Approach - Version II
- General description of the entire experiment
- Description of the apparatus with diagram(s)
- Description of test articles or subjects
- Description of what will be measured (test matrices, independent and dependent variables, parameters)
- Discussion of errors, i.e., can you identify the data (the key pieces of information you need to achieve the experimental goals) from the noise?

Experiment Design - Version III
- Design and construction methods for apparatus
- Design and construction methods for test specimens (if required)
- Design of human experiment protocol (if required)
- Measurement systems
- Any make/buy decisions on equipment
- Safety concerns (use of humans, hazardous materials, etc).

Data Analysis - Version III
- Planned methods for data reduction and error analysis
- How will this data prove/disprove hypothesis and meet project objectives and success criteria?

Project Planning - Version III
- Budget
- Detailed Schedule (for 16.622 semester)

Facilities, tech staff support and space needed - Version III

Summary -Version III

List of References - Version II

Appendices - Version III

As appropriate for your project, include the following appendices or others. The order of appendices is not significant.

Appendix A: Detailed drawings of apparatus or pseudo code

Appendix B: Detailed parts list

Appendix C: COUHES approval form if required

Appendix D: Specification sheets for purchases equipment or code

## Submission of Written Assignments

Four hard copies are required for all written assignments. These should be single-sided and stapled to ease the reading and correction process. In addition, each assignment should be submitted electronically in PDF and Word format (if using Word). In addition, an electronic submission of the Oral Presentation is expected. Further instructions about the electronic submissions will be given as the date approaches. At the end of the semester, we will ask if you are willing to grant the course faculty permission to use material from your written or oral presentations for future classes. Such permission is purely voluntary and in no way affects the evaluation of your performance in the class.

# Appendix C: 16.622 Deliverables

## Notebooks

Details of Notebook use and grading are provided in Appendix D: Laboratory Notebooks.

**Milestones**

| | |
|---|---|
| September 23, 4 PM | Notebooks due |
| October 16, 4 PM | Notebooks due |
| November 13, 4 PM | Notebooks due |

## Preliminary Requirements

There are a few preliminary requirements that you need to address in the first two weeks of the term. (These apply only if your did not do them last spring in 16.621.)

**Milestones**

| | |
|---|---|
| September 3, 3-4 PM | Safety Lecture |
| September 5, 5 PM | Complete required shop training |
| September 5, 5 PM | Select and secure work area |

**Safety Lecture**

**You cannot begin your project until you have completed this requirement.**

Every 16.622 student must attend a safety lecture, given on or near the first day of class, unless he or she has had a departmental safety lecture within the past year. If you were not at the lecture last term or are unable to attend this lecture, see Laboratory Staff about scheduling an alternate date.

**Machine Shop Training**

16.622 students who plan to use the machine shop must also sign up for and attend the shop training before beginning using any shop equipment. The purpose of the training is to provide familiarity with the safe operation of shop equipment. If you have not been through this, sign-up sheets will be posted in the machine shop before registration day. Sign up immediately to complete the shop training during the first week of class.

**Lab Space and Tools**

Lab space and storage space for your project can be secured from the laboratory staff or your project advisor. Please be respectful of other's lab space and equipment around you.

Toolboxes are available for 16.622 students for use on their projects. They may be obtained from Laboratory Staff and it is your responsibility to secure their contents.

In determining their portion of your grade the technical staff will take into account the clean up of your project area and the return of all tools at the end of the term.

## Team Meeting 1

The purpose of this meeting is to help you get off to a quick start and assure that you, your project advisor, and the 16.62x staff are "all on the same page". We will work with you to identify any potential problem areas.

**Milestones**

| | |
|---|---|
| September 2-5 | Sign up for team meetings on Gelb Shop door |
| September 9, 2:15-5PM | Team meetings with the 16.62x staff |

Time for these meetings is 15 minutes, so you are encouraged to come prepared with a list of issues to discuss. This meeting will start with a brief informal presentation of your hypothesis, project objective, success criteria (1 vugraph), and an experimental overview, schedule, and list of materials (3 minutes, 3 or 4 overheads) using charts from your 16.621 final presentation You should also bring a complete set of engineering drawings, wiring schematics and parts lists as appropriate for your project. Presentation will be with overhead vugraphs. PC projection will not be allowed for these working sessions.

The times for your remaining semester presentations and meetings (listed below) will be arranged at the time of the first team meeting. **Be sure you and your advisor bring your semester calendars with you.**

## Oral Progress Report

The Oral Progress Report is a briefing on the status of the project.

**Milestones**

| | |
|---|---|
| September 23, 1-2PM | Communication class on progress reports |
| October 2, 2:15-5 PM | Oral Progress Reports given |

Because the Progress Reports must stand alone, a brief review of motivation, background, objectives, success criteria and approach is required. The reports should present the problems encountered in the execution of the plans, outline the steps necessary to address the problems, and cite anticipated changes in design or program.

Each team will have 8 minutes to present their progress report. This will be followed by a 5-minute question and answer session. Time limits are strictly followed and speakers will not be permitted to continue beyond the limits. For this reason it is important that members of a team rehearse well in advance for each presentation and carefully divide the time among the speakers.

## Team Meeting 2

The purpose of this meeting is for the 16.62x staff to help you address any problems and ensure that your project concludes successfully. Time for these meetings is 15 minutes, so you are encouraged to come prepared with a list of issues for discussion.

**Milestones**

| | |
|---|---|
| October 21, 2:15-5 PM | Team meetings with the 16.62x staff |

This meeting will start with a brief informal presentation of your project objective an experimental overview, and schedule (3 minutes, 3 or 4 overheads.) You should also bring samples of any data collected to date (preferably in the form of tables or plots).

## Final Report

The final report has both oral and written deliverables. These deliverables will be modeled after an AIAA Student Conference presentation and paper.

**Milestones**

| | |
|---|---|
| November 18, 1-2 PM | Communications class on writing a final report |
| November 25, 12-5 PM | Oral Presentations |
| December 9, 1 PM | 4 copies of final report due |
| December 11, 4 PM | Electronic copy of final report due |

**Presentation**: Each team will have 13 minutes for their final presentation. This will be followed by a 5-minute question and answer session. Time limits are strictly followed; speakers will not be permitted to continue beyond the limits. For this reason, it is important that members of a team practice well in advance for each presentation, carefully dividing the time among the speakers.

**Written report**: The final report should contain a comprehensive discussion of all elements of the project, with a focus on the results. The presentation should be such that a reader can thoroughly understand the aims of the project and what the work accomplished. The level of discussion should be such that, given the same resources, the reader could redo the experiment in all its important details. While the emphasis is on the results, it is necessary to include mention of the motive for the work, clearly state the hypothesis, objectives, and success criteria, and outline the approach and essential details of the experiment. Data should be presented in comprehensive and concise formats. Conclusions should be related to specific observations and, where possible, to specific elements of the data.

The written report should be concise and direct. It should be long enough to contain all relevant information cited above, but short enough to avoid inflicting boredom on the reader. Raw data do not belong in the Final Report unless such data are of significant interest or necessary for interpretation. Appendices may be included when warranted.

Please NOTE that team partners usually write the final report together, indicating who has taken responsibility for what section. Sometimes partners do decide to write separate reports. If you will be jointly authoring your final report, you will be asked to prepare an outline showing the sections that each partner is contributing to. It is required that this outline be signed by each partner indicating acceptance of the plan. The outline will be due in the November 18 communications class.

For information about formatting, reference, and citation guidelines for all written reports, refer to the Style Guide.

**Outline for 16.622 Final Report and Presentation**

Front Cover

Informative Abstract (approximately 200 words)

Introduction
- Background including motivation for project
- Hypothesis
- Brief overview of previous work (with appropriate references)
- Brief summary of proposed project and its expected value to the technical community (1 paragraph)

Objective and success criteria (clear and concise, 1 paragraph)

Literature Review
- For each study, discuss as appropriate:
  - Theoretical or experimental approach
  - Major findings
  - Limitations or shortcomings of study
- Summarize the previous work and why the additional study you propose will add value to the body of knowledge of this topical area.

Description of Experiment
- Overview of experiment (a one or two paragraph summary of what was done). Description of test apparatus and test articles, with illustrations. Description of any important fabrication steps.
- Scope of the tests
- Method of the tests, including calibration and error mitigation
- Test matrices

Results
- Description of experiment results, both in graphs/visuals and in textual form

Discussion
- Analysis of results
- Comparisons to theory, expected results or previous work
- Discussion of large errors
- Relation of results to hypothesis

Summary and Conclusion
- Summary of findings from the analysis/discussion related to objectives
- Assessment concerning hypothesis (must be supported by the Discussion)
- Suggestions for future work

List of References

Acknowledgements

Appendix A: Supporting Data (Optional)

Other Appendices as appropriate

## Submission of Written Assignments

Four hard copies are required for all written assignments. These should be single-sided and stapled to ease the reading and correction process. In addition, each assignment should be submitted electronically in PDF and Word format (if using Word). In addition, an electronic submission of the Oral Presentation is expected. Further instructions about the electronic submissions will be given as the date approaches. At the end of the semester, we will ask if you be willing to grant the course faculty permission to use material from your written or oral presentations for future classes. Such permission is purely voluntary and in no way affects the evaluation of your performance in the class.

## Appendix D: Laboratory Notebooks

You are required to have a **bound notebook with numbered pages**. A Computation Book is recommended (152 pages, 9-3/8 x 11-3/4). The "oversize" format is particularly suited for inserting 8-1/2 x 11 sheets that might contain specifications, graphs, data, etc. Inserted pages should be glued or taped in place. Avoid the use of staples or paperclips, as they tend to make the notebook very bulky and difficult to handle, and are not reliable as mounting devices.

As a professional, you will find that it is important to document your work, not only for your own reference, but also for use as supporting evidence, if and when patents for work are issued or contested. The notebook is also an indicator of the regularity of your meetings with your faculty advisor and is used by course faculty in assessing your progress.

As an aid to your project, the value of good note taking becomes apparent when you begin to analyze your data or write a report or a paper. There are no hard and fast rules for taking notes but you should keep in mind that your notebook is an important communication channel to the course staff and, perhaps more importantly, to yourself. An illegible or incoherent set of notes will be of little help.

Above all, the notebook represents a running record of your observations and results. As such, it is a historic document in the sense that all entries represent records of events at the time of entry. Whether you deem an observation correct a day or a year later is irrelevant to the record at the time of entry. That record should stand regardless of updated impressions and conclusions. For these reasons, it is essential that erasure, cross-hatching, ink blotting, or page tearing destroy **no** part of the record. If at any time you feel that an earlier entry should be reconsidered, do so by indicating the entry in brackets, placing a marginal note in an adjacent space, and specifying the reasons for reconsideration with a statement of your current ideas about the issue.

Some suggestions follow that may assist you in keeping a good notebook:

**Date each entry and record the time of day** at several intervals during the course of the experiment. The times of entries are important for many reasons. For example, sudden or progressive instrumentation problems, discovered later, may make it necessary to determine the extent to which data have been affected. As other examples, it may be necessary to refer to meteorological data to retrieve values of barometric pressure or air temperature that were not recorded, or it may be necessary to demonstrate "prior discovery" when applying for patents. It is for situations such as these that it is necessary to have a notebook with numbered pages with dated entries.

**Write clearly in ink.** You don't have to be extremely neat, but it helps for others to be able to read your writing. Notes in pencil fade with time; therefore, **all** written entries should be made in ink. Erased entries are unacceptable.

**Title each entry.** A column of numbers with no label or explanation may mean something to you today, but a month or two later (or a term later) it may be impossible to decipher. You

should write a few sentences about what you are doing and why, so that there is some continuity in your notes. Ideally, someone not familiar with your work should be able, more or less, to tell what you have been doing by reading through your notebook.

**Draw a schematic of all experimental set-ups.** It is important that you thoroughly document the evolution of your experimental apparatus (they all evolve). In some cases, an error in the data may be traced to the experimental set-up and sometimes corrections are possible. It is not necessary to draw a schematic of your set-up each and every time you take data; you may refer to a previous sketch provided it is identical to the set-up you are currently using.

**Within reason, record as much data as possible.** You don't have to go to extremes, but the more information you have about an experiment, the overall set-up, etc., the more secure the analysis, especially if problems arise.

Data can be transferred from one notebook to another in the event that one partner is taking data while the other operates the experiment. In general, however, **each notebook should be an individual effort**, documenting the project's progress. If data are directly recorded to computer disk, indicate the file location, name, and format.

**Write it down!** If you have a thought about your project, such as a change you want to make, an addition to a list of parameters, something new you want to try, make note of it in your notebook. Make a habit of it; be sure to date new information. Many times these ideas arise spontaneously, and it is very easy to forget about them. It is also a good idea to occasionally review your notes to refresh your memory on your latest thoughts, problems, etc.

**Do not leave blank pages** in the notebook.

Remember, a neat notebook is nice, but a complete notebook is crucial. Put everything in your notebook and not on scraps, envelopes, or paper towels.

## Notebook Grading

Your notebook will be collected 3 times during the semester for grading by the course faculty. Notebooks are graded on a 3-point scale at each collection.

You must meet with your advisor at least twice during each notebook-grading period. It is your responsibility to present a record of these meetings in the form of entries in your notebook initialed and dated by your advisor. These two meetings with your project advisor in each grading period count for 1/2 point each for a total of 1 point.

The remaining 2 points per reporting period are allocated based on the overall quality of your notebook as follows:

**2 points:** clear description of progress, allowing someone to accurately reproduce the project and to understand the issues that you had to resolve. Entries are dated, titled, and in ink.

**1 point:** an overall description of the project, but without sufficient detail to allow someone to accurately reproduce your experiment or to fully understand the design issues.

**0 points:** unorganized notes that do not provide insight into the issues or provide guidance for someone to reproduce your experiment.

## Appendix E: Awards

The Experimental Projects Course offers each student the unique opportunity to demonstrate originality in thought, individual skills in modeling and design, and in the development and execution of an experiment. All students and/or teams in 16.622 are considered for the following Departmental prizes awarded at the end of the academic year at the senior recognition dinner:

**Admiral Luis de Florez Award** for "original thinking or ingenuity" – as demonstrated by the *individual* effort of the student, not the ideas and suggestions of his advisor, instructors, or an advisory team.

**Leaders for Manufacturing Undergraduate Prize** awarded to one or at most two 16.622 teams "who have used their project to directly deal with issues that are related to the interaction between manufacturing and engineering through demonstration of modern manufacturing processes in the execution of their project through analysis of the origin of manufacturing errors or error analysis of their data or both.

**Apollo Program Prize** given to an Aero & Astro student who "conducts the best undergraduate research project on the topic of humans in space." The Apollo prize may also be given to a student for participation in a successful Course 16 design project.

**Thomas B. Sheridan Award**, given to an Aero & Astro or Mechanical Engineering undergraduate student whose research or design project best exemplifies creativity or improvement in human-machine integration or cooperation."

**United Technologies Corporation Award**, given to an Aero & Astro student "for outstanding achievement in the design, construction, execution, and reporting of an undergraduate experimental project."

**Andrew J. Morsa Prize** given to undergraduate students "for demonstration of ingenuity and initiative in the application of computers to the field of Aeronautics and Astronautics."

# Appendix F: Reference Booklist

## Experimental Design References

Resources that have been found useful are held in The Seamans Aerospace Library:

Beckwith, T. G., *Mechanical Measurements*, 5th Edition, New York: Addison-Wesley, 1993.

Jensen, C. H., *Engineering Drawing and Design*, New York: Gregg Division, McGraw-Hill, 1990.

Brown, Sally A., *500 Tips for Research Students*, Philadelphia: Kogan, 1995.

Hansman, R. John, *Measurement, MIT Video Series*. An excellent series of 8 videos on various aspects of measurements.

The following texts on experiment design are available at Barker Library:

Cox, D. R., *Planning of Experiments*, New York: Wiley, 1958.

Bragg, G. M., *Principles of Experimentation and Measurement*, Englewood Cliffs, N.J.: Prentice-Hall, 1974.

Diamond, W. J., *Practical Experiment Designs for Engineers and Scientists*, Belmont, Calif.: Lifetime Learning Publications, 1981.

Hicks, C. R., *Fundamental Concepts in the Design of Experiments*, New York: Holt, Rinehart, and Winston, 1982.

Doebelin, E. O., *Engineering Experimentation: Planning, Execution, Reporting*, New York: McGraw-Hill, 1995.

## Writing References

On-line writing references are available.

Of particular interest for 16.621/622 is the Mayfield Electronic Handbook of Technical and Scientific Writing, which can be accessed from the above web address.

## 16.621/16.622 Sample Reports

PDF files of past semesters reports are available for viewing at the Seamans Aerospace Library. Ask the staff for the 16.621/16.622 CD. Samples are also available on the 16.62x Web site.

You'll find additional material at http://cdio-prime/aaarchive/aeroastro/index.htm

## Appendix G: Title Page Format for All Written Material

**<PROJECT TITLE>**

**<type of report> (e.g., "Final Report")**

**16.62x <X = 1 or 2>**

**Fall 2003**

**Author: <your name here>**

**Advisor: <advisor's name here>** **Partner: <partner's name here>**

**<date of submission>**