Abstract

This paper first reviews the concepts, design and operation of a complete engineering program assessment system, and then addresses issues of concern in system maintenance and faculty participation for such a system. The system review serves to equip those who are unfamiliar with assessment systems to be able to develop one, and those that are familiar with such systems to evaluate the system presented. The review clarifies the contrast of old and new cultures (units and topics versus outcomes and assessment), presents the basic concepts and terminology of assessment/evaluation/enhancement, describes the design and components of the system, and explains the data flow and component interrelationships. The remainder of the paper then addresses issues of system maintenance and faculty participation in terms of periodic processes and cycles, task groupings and schedules, and estimated faculty level of effort. A position is taken for how the system can be simplified to minimize faculty effort, and an argument made for which elements are essential and must necessarily be retained and emphasized.

I. Introduction

San Jose State University’s College of Engineering formed a college-wide Assessment Task Force (ATF) comprised of department representatives about three years prior to the College’s Fall 1998 ABET evaluation visit. The ATF proved to be an invaluable forum for sharing best practices, providing mutual encouragement and help, and stimulating departmental action and participation. Whereas the “old culture” of program evaluation focused on units and topics with minimal constituent input (see Figure 1), the generic assessment system design adopted by all five departments through the ATF uses embedded loops of course, program and department assessment processes (see Figure 2). Results of the accreditation visit proved the value and effectiveness of the College assessment system design as it was initially implemented in seven degree programs. Aerospace Engineering and Mechanical Engineering were two of the seven baccalaureate programs reviewed by the visit that employed this assessment system.

This paper extends the material of an earlier paper\(^1\) to include issues of system streamlining and maintenance, planning of periodic processes, and faculty participation and workload. It is a presentation-only abbreviated form of a recent extended workshop\(^2\) in best assessment practices. The workshop presented the material in more detail and included discipline-based team exercises to put system processes into practice.

In considering the “old culture” (Figure 1), an overstated critique would be that it typically had five distinctive features, each of which is now considered inadequate and unacceptable:
• There is a lack of cogent (much less interrelated) objectives at department, program and course levels.
• There is only minimal constituent input into curricula content and objectives, with the accrediting agency providing prescriptive input (topics and units) and employers providing reactive input (shortcomings of our graduates).
• Large numbers of individual, voluminous Course Notebooks describing course content and enclosing student work are the basis and primary support for program evaluation.
• Informal faculty review and discussion of capstone courses as well as the individual major courses are the only “integrative” process for improving overall program.
• Formal, good-practices assessment processes for ensuring evaluation of student learning and providing means for program improvement are in general not used or present in department processes.

In contrast, a new assessment system design (Figure 2) includes the following:
• Degree Program Educational Objectives are supported by achievement of specific of Outcomes.
• There are identified constituents and processes for their participation in defining objectives and outcomes, as well as determining student achievement of them.
• An Outcome Notebook document for each outcome provides the focus for evaluating the integrative growth in achieving the outcome by graduation.
• A variety of assessment methods is employed at various stages in the student’s education to determine performance in each of the desired outcomes.

II. System Terminology and Design

Under the general heading of assessment, we have standardized on particular terminology for the various phases of the continuous improvement cycle as follows. The assessment phase of the cycle answers the question “How well are our students achieving the desired outcomes (and hence educational objectives)?” The evaluation phase answers the question “What changes do we need to make to improve outcome achievement?” And the enhancement phase involves implementing the changes, the impact of which is then assessed in the next cycle.

The basic system design involves defining high-level engineering degree program educational objectives that are supported by a matrix of program outcomes (typically taken initially to be the ABET a-k outcomes). The program outcomes are measurable, and are more directly correlated with individual course learning objectives than are the program objectives. Courses are formulated in terms of course goals (the instructor’s goals for the material) and student learning objectives (what the students will be able to do – gained skills - upon course completion). Student learning objectives in each course must directly support achieving one or more program outcomes at some level of achievement, e.g., introductory, advanced, design. In summary, learning objectives (skills) from the courses must map into program outcomes which themselves map into program educational objectives. The integration and growth in achieving an outcome during progress toward the degree is fundamentally documented and described by the Outcome Notebook. Outcome notebooks replace course notebooks as the central documentation for program assessment (and accreditation). This reflects the change of accreditation focus from being primarily on topics and units to being primarily on outcomes achievement. It is argued
that only with such documentation and focus can the new culture really track and document the vertical integration and growth in terms of outcomes that are now the program focus in the new culture.

As visualized in Figure 2, the overall system design has two basic features. The first is the structure of a nested series of three assessment/evaluation/enhancement loops with the lowest level (individual course assessment) supporting the intermediate level (outcome assessment) that in turn supports the highest level (program assessment/enhancement). Content of the education flows from course up to program level, and requirements for revision and improvement flow down from program level to course level.

The second basic feature is the integration of a longitudinal series of assessment data collections. The collection tools fall naturally into two categories that are distributed from (potentially) freshman through senior years and beyond into professional practice:

- Traditional methods for faculty evaluation of student knowledge and skills within each course including the capstone course and senior project, e.g., course deliverables and grades.
- Self-perception and external perception methods, e.g., surveys

The tools and categories listed are not exhaustive, for the engineering education assessment literature describes many more types of methods.

III. System Components

Major system components include the following, which are discussed in top-down sequence:

- Program Mission and Educational Objectives
- Program Outcomes, Performance Criteria and Metrics
- Outcome Flowchart
- Outcome Notebook and Course Journal
- Course Goals and Student Learning Objectives
- Assessment and Enhancement Schedule and Cycle (see Section IV)

The degree program Mission Statement (see Figure 3) is often embedded in or essentially equivalent to the department mission statement, and is aligned with University and College mission statements. Program Educational Objectives (Figure 3) are high-level objectives expressing, for example, the types of graduates to be produced and the career opportunities for which they are to be equipped. Program Outcomes (Figure 3) are measurable results and skills the achievement of which will ensure achieving the Educational Objectives, as the former articulates and maps into the latter (see Table 1).

To assess achievement of an Outcome requires defining criteria against which to measure performance and the setting of quantitative standards and thresholds. The Performance Criteria (see Table 2) provide the criteria and the Performance Metrics (Table 2) set the standards. In our experience Performance Metrics are one of the most challenging components for a department faculty to discuss, define and agree on.

The education and learning involved in a degree program is established and accomplished primarily through coursework that accumulates in completing a curriculum. Having defined the
mission, objectives, measurable outcomes and criteria for the program, specific courses are then identified as the key ones supporting each outcome (see Table 3). It is wise to initially choose just a few courses to support each outcome since an extensive and matrixed documentation will be required from them. In making these choices, vertical integration must be addressed, i.e., courses should chosen if possible from freshman through senior years. The most central aspect of a new-culture assessment system is assessment of growth and increase in outcome achievement as produced by hierarchal curriculum design. The vertical growth is summarized in an Outcome Flowchart (see Table 4) that is a key inclusion in the Outcome Notebook.

The Outcome Notebook plays the role for outcome assessment and documentation that the Course Notebook under the old culture did for topics and units. Since accreditation evaluation under the new culture focuses primarily on outcomes assessment and secondarily on topics and units, the Outcome Notebook becomes a central document for evaluation. It draws together and integrates in one location for the accreditation visitor as well as department enhancement processes all interacting materials involved in developing and assessing outcome achievement. It is the basis for department outcome evaluation and enhancement processes. Table 5 shows an example Outcome Notebook Table of Contents.

With outcomes as the central feature in the new culture and the Outcome Notebook as a new initiative, the old-culture Course Notebook must be reduced in role and content, and consume less faculty effort. The result is redefined as a Course Journal, an example Table of Contents for which is shown in Table 6. Although student work documenting accreditation-required topics (under ABET’s “Professional Component”) will probably remain documented in the Course Journal, the main purpose for the Journal is to serve as the department’s means for documenting and controlling the nature, content and assessment of the course as it serves growth in the outcomes the course supports. It therefore answers to requirements of the Outcome Champion for enhancing outcome achievement. It is especially useful for providing guidance and promoting consistency and continuity for multi-section courses and courses taught by different faculty members.

The most important element in each course in the curriculum is the statement of Course Goals and Student Learning Objectives. Course Goals are high-level goals or targets the Instructor defines as being what she/he wants the course to accomplish or provide the student. Typically 3 to 6 in number, they usually state the main foci of the course as expectations of what the course will provide students. In that sense, they are uncoupled from what skills and growth the students may actually achieve; but achievement of course goals unfortunately does not equate to student learning achievement! Student Learning Objectives (SLOs) are statements of specific and measurable skills students will have acquired upon completion of the course. Ranging from 6 to perhaps as many as 20 or 30, they describe the skills, but do not state the distribution of student achievement or levels of proficiency since these are left to be measured in the assessment process. It is especially important to note that the ABET-mandated Course Syllabus (see example, Table 7) required for the Program Self Study report mandates inclusion of Course Goals and SLOs, and the SLOs must be explicitly related in the syllabus to Educational Objectives of the degree program. This is the essential “bottom up” curriculum design feature now formalized and mandated by ABET (and it makes good sense for continuous program improvement).
To summarize the bottom-up educational process, achievement of one or more Student Learning Objectives in one or more vertically integrated courses leads to achievement of a Program Outcome, and achievement of one or more Outcomes leads to achievement of a Program Educational Objective. The assessment/evaluation/enhancement process then flows downward by determining the extent of Outcome achievement, defining course/curriculum changes that would increase Outcome achievement, implementing these, and then repeating the cycle.

IV. System Maintenance and Faculty Participation

To be complete, assessment system design requires a periodic and cyclic operational plan of activities that indicates “who does what, when.” The construction of the operational plan can have a great impact on workload and roles of the faculty, administration, and staff. We conclude the paper by briefly addressing three topics here: 1) an example of such a plan designed to promote collegiality and minimize faculty workload; 2) a description encompassing the major departmental roles of faculty and where the assessment activity fits in; and 3) an estimate of the annual workload the roles impose on faculty. Taken as a whole, these considerations are key to successful and realistic establishment of an ongoing assessment system, faculty participation and teamwork, and good management of the entire process. In other words, designing an assessment system can be fun, and installing it can bring an early growth of knowledge and satisfaction for the faculty. But whether or not it becomes a permanent part of the culture, and whether or not it provides for continuous program improvement will depend on installing a realistic, collegially-accepted operational plan that minimizes faculty workload and makes routine all the activities and processes!

An operational plan indicates which activities are to be performed at which times, who is to perform them, and what steps and resources they involve. Figure 4 is a partial example that shows a composite timeline and schedule (based on a semester system), separate indication of assessment, evaluation, enhancement, and data collection intervals, and some of the steps involved in each activity. It is this kind of beginning that must be made for a plan to be developed. Here, Outcomes are grouped for assessment to decrease individual faculty workload, since this allows revisiting the Outcomes only once each three years (twice in an ideal accreditation period), and thereby means the team is “on duty” about half the time in a 3-year cycle. Outcome grouping and Outcome Champion teaming also serves for mutual encouragement and guidance. A brief outline of the steps involved in the assessment term, evaluation term, and enhancement term for each team is noted. And collection schedules for assessment data in terms of coursework and noncoursework, e.g., surveys, are indicated. But this figure leaves many issues unaddressed. For example:

- What student coursework is to be collected, how is it to be shared among teams and how is it to be returned to the students?
- How are Outcome Champions to go about obtaining the data and collaborating with course Coordinators to define and obtain needed course changes?

The ways in which these important details will be resolved depends on individual department cultures and environments. It is expected that the faculty may participate in designing survey content (as Outcome Champions). But to minimize faculty workload, department administration and staff will provide the support for producing and administering the surveys as well as
providing statistical analysis of the results; similarly, to the extent possible, concerning collection and distribution of student work.

Regarding faculty roles and participation, departmental faculty should participate in several roles in instructional programs: Course Coordinator, member of a discipline team (e.g., thermofluids), Champion of an Outcome, member of a grouping of Outcome Champions for an assessment cycle, and department-wide deliberation and discussion of curriculum effectiveness and changes. Figure 5 attempts to visualize the different roles, their periodicity and content, and the interactions between the roles. It is apparent that faculty needs to be adept at remembering which role they are performing at a given time and how their efforts integrate into the whole!

Finally, every faculty is owed a rough estimate of the workload if they are to be expected to participate in establishing and maintaining an assessment system. I suggest the following as an estimate, building off Figure 4:

<table>
<thead>
<tr>
<th>Duty of Each Faculty Member</th>
<th>Periodicity</th>
<th>Level-of-Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Coordinator-maintain Course Notebooks for 2 – 4 courses</td>
<td>Annually</td>
<td>½ day</td>
</tr>
<tr>
<td>Outcome Champion-maintain 1 Outcome Notebook</td>
<td>Every 3 years</td>
<td>½ - 1 day</td>
</tr>
<tr>
<td>Outcome Assessment Team-analyze data, define, recommend and implement changes in appropriate system components</td>
<td>1-1/2 out of 3 years</td>
<td>1 day</td>
</tr>
<tr>
<td>Discipline Team-meet to review, define &amp; recommend curriculum changes</td>
<td>Annually</td>
<td>½ day</td>
</tr>
<tr>
<td>Department Meetings/Discussion-hear, discuss decide on recommended curriculum and system changes</td>
<td>Annually</td>
<td>2 - 3 meetings</td>
</tr>
</tbody>
</table>

Total Equivalent Annual Average: 1-1/2 to 2 days

Please note that the formal assessment system has added only about 1 day of work annually to the duties that faculty carry on even without an assessment system (discipline teams and department meetings). Exercising discipline in system design, constraining content and work to be only that which is absolutely necessary, using administrative and staff support wherever possible, and making clear and routine the various processes will result in approaching this minimum assessment-system added workload of about 1 day per year. And it will be well worth it!
V. Conclusion

We have described the essential elements of a complete engineering degree-program assessment system that provides best practices for ongoing continuous improvement and fulfills ABET accreditation requirements. The system has been presented in visual form, the old and new cultures contrasted, and system design discussed component-by-component, with examples given for all major components. Data flow and interactions have been explained. The practical realities of an operational plan have been described at a simplified level. Faculty roles and estimated workload with suggestions for its minimization have been presented.

We conclude with the following all-important conclusions that we implore the reader to accept and put into practice:

• Every engineering degree program needs to establish a system such as this one not just for satisfying accreditation requirements, but primarily to serve as a permanent part of the culture for ongoing continuous program improvement.
• Any such system must involve participation of all faculty, must be collegially designed and implemented, and must take pains to minimize operational faculty workload.
• Any such system must preserve the central focus on outcomes achievement, and must therefore preserve and make first priority the Outcome Notebook documentation concept and Outcome tracking, as opposed to the old Course Notebook concept and emphasis.
• In establishing an assessment system, it is absolutely critical to have a proper management and operational plan, agreed to by all, that clearly defines and installs cyclic processes, roles and interactions.

Bibliography
1. Desautel, D. Design and Implementation of a Mechanical and Aerospace Program Assessment Model, Session 1302, ASEE Annual Conference & Exhibition, June 2000, St. Louis Missouri

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Figure 1: “Old Culture” Program Assessment & Enhancement Process

- Informal Department Mission & Goals
- Program Curriculum

**Open Department “Loop”**

- Program Enhancement
- Informal Evaluation
- Informal Assessment

**Closed Program Loop**

- “Units & Topics”

**Closed Course Loop**

- Course Enhancement
- Course Notebooks

**Degree Program**

- Entering Students
- Graduating Seniors
- Capstone Course Senior Project

**Alumni**

- Employer Survey

**Employers**
Figure 2: EC2000 Program Assessment & Enhancement Process

University, College & Department Mission & Goals

Advisory Board
Industry
Students
Alumni
Faculty

Program Educational Objectives

Department Loop

Program Enhancement

Constituent Data

Outcomes & Performance Criteria

Program Evaluation

Program Assessment

Program Loop

Entering Students

Entering Surveys

Course Enhancement

Each Course: Goals & Learning Objectives
Grade Statistics, Assignments
Quizzes, Exams, etc

Course Journal

Degree Program

Focus Group
Junior Surveys

Outcome Notebook

Graduating Seniors

Capstone Course
Senior Project
Exit Test & Survey

Employer Survey

Alumni

Alumni Survey
Figure 3: Example Mission & Goals Statements – University, College and Department

Mission Statements

Mission and Goals of San Jose State University

The University Mission is:

In collaboration with nearby industries and communities, the faculty and staff are dedicated to achieving the University’s mission as a responsive institution of the State of California:

To enrich the lives of its students, to transmit knowledge to its students along with the necessary skills for applying it in the service of our society, and to expand the base of knowledge through research and scholarship.

The University’s goals are that its graduates have:

- In-depth knowledge of a major field of study.
- Broad understanding of the sciences, social sciences, humanities, and the arts.
- Skills in communication and in critical inquiry.
- Multi-cultural and global perspectives gained through intellectual and social exchange with people of diverse economic and ethnic backgrounds.
- Active participation in professional, artistic, and ethnic communities.
- Responsible citizenship and an understanding of ethical choices inherent in human development.

Mission and Goals of the College of Engineering

The College Mission is:

To be a leading provider of high quality, practice-oriented engineering graduates through excellence in education, research, and scholarship.

The College of Engineering goals are that its graduates have:

- Skills in applying engineering theory to the design and development of products, and processes for their manufacture/construction.
- Strong communication, critical thinking and interpersonal skills.
- Proficiency in information technology.
- Ethical behavior and concern for colleagues, society, and the environment.

Mission of the Mechanical & Aerospace Engineering Department

The MAE Department mission is:

To serve society, the public sector, and private industry by:

- Providing undergraduate and graduate mechanical and aerospace engineering education that equips students with the engineering knowledge, modern applications and lifelong learning skills required for service in the engineering profession and industry.
- Contributing to the development and application of knowledge through faculty scholarship.
- Preparing students for the modern professional-practice environment.
Department of Mechanical & Aerospace Engineering

Educational Objectives of the BSME and BSAE Programs

The Educational Objectives for these Programs are to:

1. Offer a **broadly based curriculum** to our students in both the ME and AE programs. Each curriculum consists of two components: courses in **engineering fundamentals** that provide a basis for professional competence and life-long learning, and courses that provide the **contemporary professional skills** required by industry.

2. Provide students with a strong foundation for **graduate studies** in ME or AE and related fields.

3. Provide students with experience in using **computers and information technology** in problem solving and learning.

4. Provide students with hands-on experience through **laboratory** courses.

5. Develop students’ ability to **communicate** and work effectively in **teams**.

6. Develop students’ understanding of **multicultural** and **global perspectives**, as well as **ethical** choices inherent in the engineering profession.

**Supporting Outcomes of the BSME and BSAE Programs**

Graduates of these Programs will:

1. Have an ability to apply knowledge of **mathematics, science and engineering**.
2. Have an ability to design and conduct **experiments**, as well as to analyze and interpret data.
3. Have an ability to **design** a system, component or process to meet desired needs.
4. Have an ability to function on **multi-disciplinary teams**.
5. Have an ability to identify, formulate and **solve** engineering **problems**.
6. Have an understanding of **professional** and **ethical** responsibility.
7. Have an ability to **communicate** effectively.
8. Have the broad education necessary to understand the impact of engineering solutions in a **global/societal** context.
9. Have a recognition of the need for, and an ability to engage in, **life-long learning**.
10. Have a knowledge of **contemporary issues**.
11. Have an ability to use the techniques, skills, and **modern engineering tools** necessary for engineering practice.
**Figure 4: Program Assessment & Enhancement Cycle**

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<tr>
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<th>AY 00/01</th>
<th>AY 01/02</th>
<th>AY 02/03</th>
<th>AY 03/04</th>
<th>AY 04/05</th>
<th>AY 05/06</th>
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<td>Outcomes 1, 4, 5</td>
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<td><strong>Non-course Data</strong></td>
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<td>Student Surveys</td>
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<tr>
<td>2, 4, 6 yrs Alumni</td>
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<td>Industry Council Input</td>
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**Outcomes Legend & Activities:**

- **Assessment**
  - i) Review collected data: Surveys, senior project, Capstone, DAC input, Course GPA, student work
  - ii) Analyze / interpret data
  - iii) Review course status & Outcome status reports

- **Evaluation**
  - i) Identify changes needed: Performance Criteria & Metrics
  - ii) Present to department faculty

- **Enhancement**
  - Implement approved changes
  - Support courses
  - Course content
Figure 5: Faculty Roles and Estimated Workload

**Course Enhancement**

**Course Coordinator (CC)**

- **Who?** Course Coordinator
- **When?** Annually, off-line
- **What?**
  - Maintain CJ contents (end of AY)
  - Enforce consistency & quality
  - Improve & upgrade content, tools
  - Revise/update EGS, SLO, CG, CAM/PAM
  - Review assignments & grade statistics
  - Prepare 1-page course status report

**Discipline Team**

- **Who?** Coordinators of Discipline Courses
- **When?** Annual meeting (<½ day end of AY)
- **What?**
  - Review 1-page course status reports
  - Prepare 1-page discipline summary with any recommendations for changes

**Program Enhancement**

**Outcome Champion (OC)**

- **Who?** Outcome Champion
- **When?** Once Every 3 years, prior to Team Review
- **What?**
  - Maintain Outcome Notebook
  - Review contents
  - Review collected data
  - Prepare 1-page outcome status report

**Outcome A&E Review Team**

- **Who?** Outcome Champions in groups
- **When?** 3-semester cycle every 3 years
- **What?**
  - Review collected data (coursework and non-coursework)
  - Analyze & interpret data
  - Review 1-page course and outcome status reports (assessment)
  - Identify recommended changes in courses as well as perf. criteria & metrics (evaluation)
  - Present recommendations to dept faculty
  - Implement dept-approved changes through OC’s and CC’s (enhancement)

**Department Faculty**

- **Who?** Entire Department FT Faculty
- **When?** Annually (end of AY)
- **What?**
  - Receive, discuss, decide on recommendations from Outcome Teams and Discipline Teams for changes in Outcomes, Courses & Curriculum

Department Administration Responsibilities:

- Administer surveys & process results
- Arrange for and organize student work collection & sharing
- Provide secretarial and clerical support to faculty
### Table 1: Example of Relationship of Outcomes to Program Educational Objectives (Mechanical and Aerospace Engineering)

<table>
<thead>
<tr>
<th>Program Educational Objectives</th>
<th>Program (and Criterion 3) Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To offer broadly based curriculum to our students that consists of two components: courses</td>
<td>Outcome 1: Have an ability to apply knowledge of <strong>mathematics, science and engineering</strong>.</td>
</tr>
<tr>
<td>in engineering fundamentals that provide a basis for professional competence and life-long</td>
<td>Outcome 3: Have an ability to <strong>design</strong> a system, component or process to meet desired needs.</td>
</tr>
<tr>
<td>learning; and courses that provide contemporary professional skills required by industry.</td>
<td>Outcome 5: Have an ability to identify, formulate and <strong>solve</strong> engineering <strong>problems</strong>.</td>
</tr>
<tr>
<td></td>
<td>Outcome 11: Have an ability to use the techniques, skills, and <strong>modern engineering tools</strong> necessary for engineering practice.</td>
</tr>
<tr>
<td>2. To provide students with a strong foundation for graduate studies in AE/ME and related</td>
<td>Outcome 9: Have a recognition of the need for, and an ability to engage in, <strong>life-long learning</strong>.</td>
</tr>
<tr>
<td>fields.</td>
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<tr>
<td>3. To provide students with experience in using computers and information technology in</td>
<td>Outcome 5: Have an ability to identify, formulate and <strong>solve</strong> engineering <strong>problems</strong>.</td>
</tr>
<tr>
<td>problem solving and learning.</td>
<td>Outcome 11: Have an ability to use the techniques, skills, and <strong>modern engineering tools</strong> necessary for engineering practice.</td>
</tr>
<tr>
<td>4. To provide students with hands-on experience through laboratory courses.</td>
<td>Outcome 2: Have an ability to design and conduct <strong>experiments</strong>, as well as to analyze and interpret data.</td>
</tr>
<tr>
<td>5. To develop students’ ability to communicate and work effectively in teams.</td>
<td>Outcome 4: Have an ability to function on <strong>multi-disciplinary teams</strong>.</td>
</tr>
<tr>
<td>6. To develop students’ understanding of multicultural and global perspectives, as well as</td>
<td>Outcome 6: Have an understanding of <strong>professional</strong> and <strong>ethical</strong> responsibility.</td>
</tr>
<tr>
<td>ethical choices inherent in the engineering profession.</td>
<td>Outcome 8: Have the broad education necessary to understand the impact of engineering solutions in a <strong>global/societal context</strong>.</td>
</tr>
<tr>
<td></td>
<td>Outcome 10: Have a knowledge of <strong>contemporary issues</strong>.</td>
</tr>
</tbody>
</table>
Table 2: Examples of Outcome Performance Criteria and Metrics (Civil Engineering)

<table>
<thead>
<tr>
<th>Outcome 3: Graduates have an ability to design a civil engineering system, component, or process to meet desired needs.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance Criteria:</strong></td>
</tr>
<tr>
<td>3a. Demonstrate an ability to design a component to meet certain constraints.</td>
</tr>
<tr>
<td>3b. Demonstrate an ability to design a system to meet certain constraints.</td>
</tr>
<tr>
<td>3c. Demonstrate an ability to integrate social, political, economic, environmental and other considerations into design of a system.</td>
</tr>
<tr>
<td>3d. Demonstrate an ability to produce effective documentation.</td>
</tr>
<tr>
<td><strong>Metrics:</strong></td>
</tr>
<tr>
<td>1. 70% of assessed student work meets minimum performance criteria.</td>
</tr>
<tr>
<td>2. At or above California State average in Structural Design on FE exam.</td>
</tr>
<tr>
<td>3. 70% of alumni indicate level 4 or 5.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outcome 4: Graduates have an ability to function on multi-disciplinary teams.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance Criteria:</strong></td>
</tr>
<tr>
<td>4a. Demonstrate an ability as a member of a team to interact and communicate in a professional manner with other members on the team.</td>
</tr>
<tr>
<td>4b. Demonstrate an ability to contribute discipline-specific input to a multi-disciplinary project.</td>
</tr>
<tr>
<td>4c. Demonstrate an ability to identify project issues that are beyond one’s expertise or the collective expertise of the team.</td>
</tr>
<tr>
<td>4d. Demonstrate an ability to integrate input from one’s discipline with input from other disciplines to solve a multi-disciplinary problem.</td>
</tr>
<tr>
<td><strong>Metrics:</strong></td>
</tr>
<tr>
<td>1. 70% of assessed student work meets minimum performance criteria.</td>
</tr>
<tr>
<td>2. 70% of internship supervisors indicate a performance level of 4 or above on ability to work effectively on a team.</td>
</tr>
<tr>
<td>3. 70% of students indicate adequate to in-depth preparation for teamwork on exit survey.</td>
</tr>
<tr>
<td>4. 70% of alumni indicate level 4 or 5.</td>
</tr>
<tr>
<td>Outcome (Faculty Champion)</td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td>2. Experiments &amp; Data Analysis (Lambert)</td>
</tr>
<tr>
<td>3. Design (Furman)</td>
</tr>
<tr>
<td>4. Multidisciplinary Teams (Wang)</td>
</tr>
<tr>
<td>5. Engr Problem solving (Agarwal)</td>
</tr>
<tr>
<td>6. Professional &amp; Ethics (Pernicka)</td>
</tr>
<tr>
<td>7. Effective Communication (Desautel)</td>
</tr>
<tr>
<td>8. Global &amp; Societal (Lambert)</td>
</tr>
<tr>
<td>9. Life-long Learning (Mourtos)</td>
</tr>
<tr>
<td>10. Contemporary Issues (Barez)</td>
</tr>
</tbody>
</table>
Table 4: Example of an Outcome Flowchart (Design in Mechanical Engineering)

<p>| Outcome #3: Graduates Must Have an Ability to Design a System, Component, or Process to Meet Desired Needs |
|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|</p>
<table>
<thead>
<tr>
<th>Semester</th>
<th>Courses</th>
<th>Elements Contributing to Outcome</th>
<th>Level</th>
<th>Assessment Methods</th>
<th>Proposals for Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman Fall</td>
<td>Engr 10 Intro to Engineering</td>
<td>Understanding of the design process</td>
<td>Introductory</td>
<td>Lab project; HW; and exam; lab exercises; written and oral report</td>
<td></td>
</tr>
<tr>
<td>Freshman Spring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sophomore Fall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sophomore Spring</td>
<td>ME 106 Intro to Mechatronics</td>
<td>Design of signal conditioning, analog and digital interfaces to electromechanical systems. Design of a mechatronic device</td>
<td>Applied</td>
<td>HW; exams</td>
<td>Demonstration of prototype hardware; presentation; project report</td>
</tr>
<tr>
<td>Junior Fall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junior Spring</td>
<td>ME 154</td>
<td>Mechanism synthesis, component stress and fatigue analysis Design of a mechanical device to solve a problem</td>
<td>Applied</td>
<td>HW; exam</td>
<td>Demonstration of prototype hardware; project report</td>
</tr>
<tr>
<td>Senior Fall</td>
<td>ME 195A Senior Project</td>
<td>Definition of a design problem State-of-the-art review Development of design specs Solution concept generation Detail design</td>
<td>Applied</td>
<td>Presentations; written report</td>
<td></td>
</tr>
<tr>
<td>Senior Spring</td>
<td>ME 195B Senior Project</td>
<td>Rapid prototyping Testing and design refinement</td>
<td>Applied</td>
<td>Hardware models; presentations; written report</td>
<td></td>
</tr>
</tbody>
</table>
Table 5: Example Outcome Notebook Table of Contents

1. Assessment Summary
   - Outcome Flowchart
   - Most recent cycle:
     - Overall Assessment Results
     - Evaluation Results
     - Enhancement Plan and Implementation

2. Outcome Performance Criteria & Metrics

3. Support Course Descriptions
   - For each supporting course:
     - Course Syllabus with Course Goals & Student Learning Objectives

4. Support Course Assessment Results
   - For each supporting course:
     - “A” Student Work
     - “B” Student Work
     - “C” Student Work

5. Assessment of Culminating Indicators
   - As appropriate:
     - Capstone Course
     - Senior Project
     - Exit Test

6. Survey Assessment Results
   - As appropriate:
     - Entering Students
     - Junior Students
     - Graduating Seniors
     - Focus Group
     - Alumni
     - Employer

Appendix: Program Assessment & Enhancement Process Diagram
Program Assessment & Enhancement Calendar Cycles & Steps
Table 6: Example Course Journal Table of Contents

1. Goals & Objectives  
   Course syllabus including:  
   Course Goals  
   Student Learning Objectives

2. Homework & Exams  
   List/Description of Homework Assignments  
   Exams  
   Quizzes

3. Labs & Projects  
   Descriptions & Assignments:  
   Computer Laboratory Assignments  
   Physical Laboratory Experiments

4. Class Handouts & Supplementary Materials  
   Copies of Handouts, Supplementary Material & Visuals  
   Reference materials  
   Lists of films and software and web sites

5. Course Assessment  
   For most recent terms:  
   Class exam distribution  
   Course grade distribution  
   Specialized Surveys
### Table 7: Example ABET Course Syllabus (Advanced Fluid Mechanics)

<table>
<thead>
<tr>
<th>Course:</th>
<th>AE 164 Advanced Fluid Mechanics</th>
<th>Semester:</th>
<th>Fall 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>This course provides students an introduction to advanced fluid mechanics that incorporates theory, experiment and computation. The course will focus on the basic theory of compressible flow including: subsonic, supersonic, 1-D and 2-D flows; stationary and moving shock waves; nozzle flow; flows with friction and heat addition. Students will also be introduced to several numerical solution techniques including method of characteristics, panel methods, and design methods for nozzles, airfoils and wings. The laboratory involves both physical experiment and numerical simulations. Students will perform the shock tunnel experiment that provides physical realization of supersonic flow and experience with modern high-speed flow measurement and visualization facilities. Students will also perform computational assignments involving developing their own programs as well as exercising existing subsonic and supersonic flowfield solution programs.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prerequisites:</th>
<th>Grade “C” or better in ME 111, ME 113; ME 130, Engr 100W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory:</td>
<td>The laboratory assignments consist of several computational assignments and the shock tunnel experiment. Each laboratory team performs 4 to 6 hours of experiments on the SJSU hypersonic shock tunnel; additional time is required to analyze the data and prepare an informal but comprehensive laboratory report. The report grade is a team grade, with allowance made for individual participation and contribution. Computer assignments are individually performed and graded.</td>
</tr>
</tbody>
</table>

**Course Goals**

1. To provide students the basic concepts of inviscid compressible flow and to apply them to solve practical problems.
2. To provide students an introduction to high-speed flow facilities, data analysis, and comparison of measurements with theory.
3. To provide students an introduction to the basic concepts, terminology and use of potential-flow and finite-difference numerical methods for design and analysis of flowfields.

**Student Learning Objectives**

Upon completing the course, the student will be able to

1. Describe the concepts and apply the theory of stationary and moving normal shocks, oblique shocks, expansion waves, and compressible flows with area-variation, heat addition, and wall friction to analyze compressible flows.
2. Use theoretical results to solve practical internal and external flow problems including nozzle flow, combustion chambers, inlets and diffusers, wind tunnels, and airfoils.
3. Use the theory to design compressible flow systems and components.
4. Describe the relationship between incompressible and compressible airfoil theory and to explain how incompressible flow results are adapted to provide compressible flow results.
5. Describe and explain concepts and operation of the shock tunnel facility and instrumentation, including data acquisition, triggering and signal conditioning, optical and photographic flow visualization methods.
6. Make, describe and explain the laboratory measurement of moving and steady shock waves, and 2-D and 3-D supersonic flows past simple body shapes, and to compare/contrast the results with theory.
7. Identify the influence of non-ideal effects (viscosity and gas chemistry) in the supersonic flow facility.
8. Describe the basic elements of potential flow and their application in numerical solution techniques, and use a vortex-lattice based commercial flowfield simulation program to solve simple airfoil modeling problems.
9. Describe and apply the basic concepts of finite-difference computation fluid dynamics: the representation of derivatives by finite differences; the conversion of the flow differential equations to finite difference equations; and their implementation of common algorithms to solve the finite difference flowfield equations.
10. Describe modern implementation of finite-difference CFD concepts for compressible flow as illustrated by MacCormack’s technique.

### Course Topics

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture Topic(s)</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Introduction</td>
<td>---------------------</td>
</tr>
<tr>
<td>2.</td>
<td>Review of thermodynamics and inviscid-flow integral conservation equations</td>
<td>---------------------</td>
</tr>
<tr>
<td>3.</td>
<td>Steady normal shock waves</td>
<td>---------------------</td>
</tr>
<tr>
<td>4.</td>
<td>Unsteady normal shock waves; 2-D flow: oblique shocks and expansion waves</td>
<td>Computer simulations</td>
</tr>
<tr>
<td>5.</td>
<td>Shock/expansion wave interactions; Shock-expansion airfoil theory</td>
<td>Computer simulations</td>
</tr>
<tr>
<td>6.</td>
<td>Quasi-1-D flow: nozzles, diffusers, tunnels</td>
<td>Computer simulations</td>
</tr>
<tr>
<td>7.</td>
<td>Quasi-1-D flow: nozzles, diffusers, tunnels; 1-D flow with heat addition</td>
<td>Computer simulations</td>
</tr>
<tr>
<td>8.</td>
<td>1-D flow with friction (Fanno); Experimental Methods</td>
<td>Shock Tunnel Experiment</td>
</tr>
<tr>
<td>9.</td>
<td>Differential flow equations; Velocity potential equation</td>
<td>Shock tunnel experiment</td>
</tr>
<tr>
<td>10.</td>
<td>Linearized airfoil theory</td>
<td>Shock tunnel experiment</td>
</tr>
<tr>
<td>11.</td>
<td>Conical Flow; Numerical Methods - method of characteristics</td>
<td>Experiment - data analysis</td>
</tr>
<tr>
<td>15.</td>
<td>Boundary layer theory: Blasius, Falkner-Skan solutions; separation criterion</td>
<td>Computer simulations</td>
</tr>
<tr>
<td>16.</td>
<td>Intro. to turbulent boundary layer theory;</td>
<td>-------------------------------</td>
</tr>
</tbody>
</table>

### Class/Laboratory Schedule

2 lecture periods, 75 minutes each, per week and approximately 12 laboratory periods a semester, mixed computer assignments and physical laboratory experiment (shock tunnel).

### Course Contribution to Professional Component

Three (3) semester units of engineering topics, approximately 2/3’s engineering science and 1/3 engineering design.

### Course Relationship to Program Educational Objectives

This upper-division engineering elective contributes to BSME and BSAE Program Educational Objectives (and Outcomes) as follows:

- **Engineering fundamentals and contemporary professional skills (Outcomes 1, 3, 5, and 11)**
  - Student applies math, science, engineering knowledge to formulate and solve ideal gas dynamics problems, and design compressible flow components (e.g., nozzles) and systems (e.g., wind tunnels).
  - Student develops computer programs and uses commercial programs to design and analyze compressible flows and subsonic/supersonic airfoils (spreadsheet or MATLAB; SUB2D; SUPER2D).

- **Engineering experimentation, effective teamwork and communication (Outcomes 2, 4 and 7)**
  - Student team performs shock tunnel experiment with different gases and models, analyzes and interprets the data, and writes a comprehensive team report.
  - Student writes brief memoranda reporting results of three computer assignments.

- **Foundation for graduate studies and recognition of lifelong learning (Outcome 9)**
  - In performing the shock tunnel experiment and using modern computer tools,
    - The student uses advanced approaches to the discipline that lay a foundation for advanced studies;
    - The student comprehends the idealistic nature of the course material and the need to go beyond it for practical application and practice.

Prepared by: ___________________________  Date: ________________