To: IIT Undergraduate Studies Committee
From: David R. Williams
Date: November 27, 2007
Concerning: Summary of Aerospace Engineering Curriculum Modifications

As mentioned during my presentation to the IIT UGSC on November 13, 2007, the MMAE Department believes the time has come to revise the curriculum of the Aerospace Engineering program. The current curriculum was designed in 1988(?) to be a modification of the Mechanical Engineering program. At that time there were approximately 30 - 40 students in the program, and we did not have sufficient resources to support a completely independent Aero degree. Over the last 10 years the number of Aero students has tripled, bringing the total to about 150 students. Although the number of students has grown, we are not ranked in the top 20 undergraduate programs by U.S. News, and our graduate program ranking has been declining. Concerns raised by ABET evaluators about the lack of Aerospace specific laboratories and weaknesses in capstone design courses need attention.

A committee of MMAE faculty met over the summer of 2007 to see what changes should be made in the Aero-curriculum to make it consistent with the top 10 degree programs in the country. We studied schools like Georgia Tech, U. Michigan, M.I.T., Air Force Academy and Embry Riddle to name a few. It was obvious from the comparison that some fundamental courses were missing, some courses we teach are not necessary, and we have strengths in certain areas that could be used to make our program somewhat unique. In the end, nine new or substantially modified courses were added to the curriculum, which includes the addition of two new Aerospace laboratory courses. The details of the changes are described in the slides following this summary. The total number of credit hours decreases by one, from 130 to 129 with the new program. If anyone has questions about the slides, please contact D. Williams (7-3192 or williamsd@iit.edu.)

IIT's Aerospace Engineering degree is the only one offered in the Chicago area, so it is truly a niche market. Our hope is to bring the program in line with the top programs in the country. The updated curriculum can be marketed to other schools and to industry to begin the process of improving our rankings. For example, D. Williams is an invited speaker to discuss the changes at the AIAA Aerospace Sciences meeting in January 2008. These changes are necessary first step toward becoming ranked in the top 20 programs in the country, which we believe is an achievable goal within the next five years.

Proposed Changes to Aero Curriculum

Committee formed following the MMAE Department Retreat May, 2007

J. Kallend, R. Lisowski, S. Nair, B. Pervan, G. Raman, D. Rempfer, S. Tin, C. Wark, D. Williams

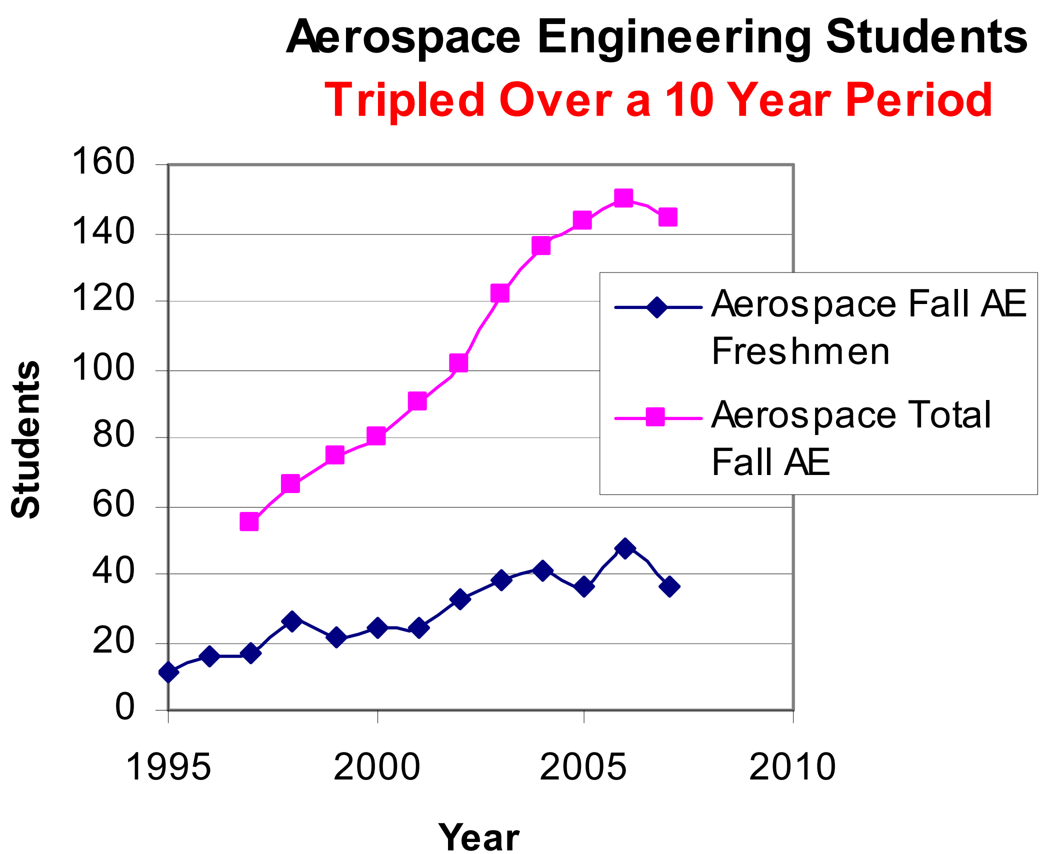
MMAE Undergraduate Studies Committee approval 10/2/07

1st Presentation to IIT Undergraduate Studies Committee 11/13/07

Motivation

- Current program established approx. 1988
  - Aerospace program is a “modification” to existing Mechanical Engineering curriculum, primarily because of the initially low enrollments. That situation has changed. Enrollment has tripled over the last 10 years (from ~50 students to ~150 students) in Aerospace Engineering.
- Previous ABET reviewers expressed “concerns” about laboratories, capstone design, the lack of aero-specific courses
- Increasing enrollment and class size stressing the ability of the department to maintain a quality program
- Committee studied 10 AE curricula around the country, then designed a new curriculum consistent with the top 10 AE programs, while emphasizing strengths at IIT (Fluid Dynamics and Materials Science.)

Enrollment Increasing, but Rankings Falling



US News & W.Report

(grad program)

31 in 2005
29 in 2006
35 in 2007
36 in 2008

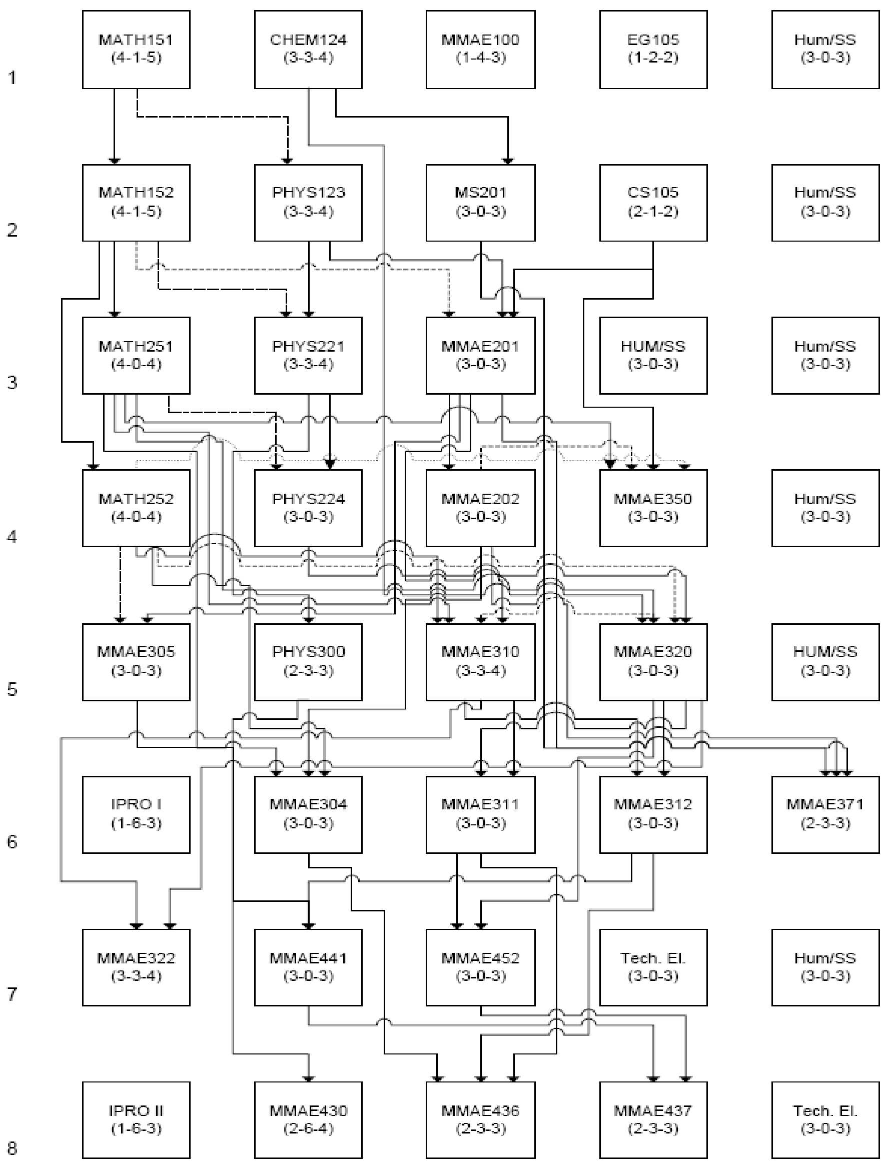
Undergrad ranking not in top 20

Opportunities

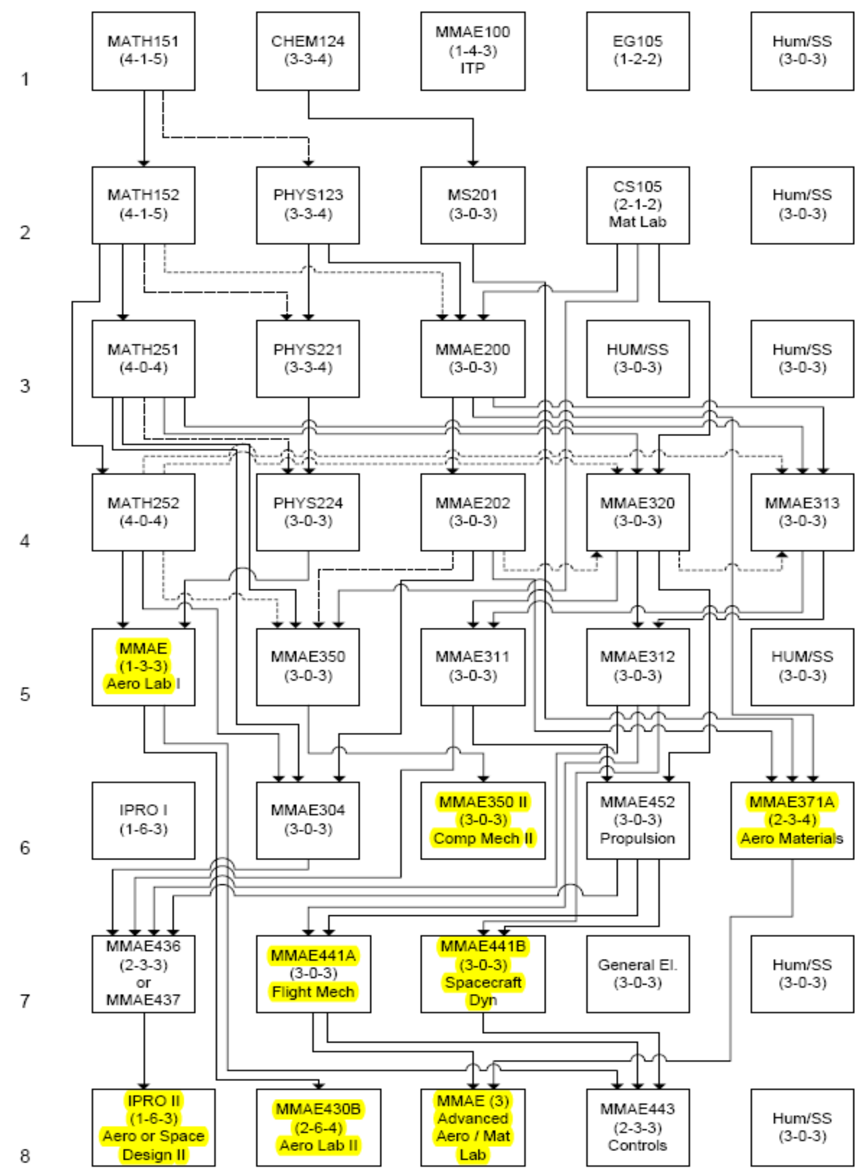
- 4-year Aerospace Engineering degree is a niche market in the Chicago area
- Strong research base in aero-fluids (FDRC), aero-controls (Pervan, Spenko), aero-materials (Tin, Wu), aero-structures (Nair, Vural), but these research activities are not coordinated.
- Update to aero-curriculum is needed to:
  - be consistent with or to exceed the education provided by top programs in the country
  - a new curriculum could be a selling point to deans and chairs through participation at AIAA, ASME, SAE meetings (chairs meetings and invited paper presentations)

Comparison of Current and Proposed Curricula

Current Curriculum



Proposed Curriculum



Summary of **New Courses**

Computational Mechanics II – applied f.e.m.

Aero Lab I – aerostatics, circuits I, statistics, intro to Labview, measurement of static forces, moments, temperature.

Aero Lab II – measurements of dynamic forces & moments, circuits II, signal conditioning, acquisition and processing, more Labview, fluid power

Aircraft Flight Mechanics – performance predictions

Spacecraft Dynamics-

Aero-design II – hands-on build and fly

Space design II – hands-on feasibility study

Advanced Aero Course – helicopters, unsteady aerodynamics, stall, flutter, and the use of computational methods to predict the loads

Advanced Aero Materials -

Courses to be replaced

- Physics 300 – some content to be covered in Aero Labs I & II – details are under discussion with Physics faculty (C. White)
- MMAE 201&305 (Statics & Dynamics) – content to be covered by existing MMAE 200 and senior level aircraft and space craft dynamics courses
- MMAE 310 is replaced by MMAE 313 - MMAE 313 is the same course without the lab component in 310.
- MMAE 371 is replaced with an aerospace materials version of the course.
- MMAE 322 Heat Transfer is replaced by a general elective – this is consistent with almost all Aerospace Engineering programs around the country
- One IPRO is listed as the second semester design course. The IPRO will be a "build & fly" course for Aero engineers or a feasibility study for Space engineers. The IPRO will be open to all students at IIT with approval of the instructor. This approach is consistent with ChemEng Dept. and the Civil Eng. Dept.

Transition from Old to New Curriculum

	Current Curriculum Courses	New Curriculum Courses
F08	Old curriculum- 1st semester soph's	New curriculum – 1st semester Fresh
S09	2nd semester soph's	2nd semester Fresh CS105 emphasis on Matlab
F09	1st semester Jr's Fluids(310), Thermo(320)	1st semester Soph's MAE 200 with ECE, BME could be large class
S10	2nd semester Jr's Aerostruct(304), Compressible(311), Aerodyn(312)	2nd semester Soph's Fluids (313), Thermo(320)
F10	1st semester Sr's Heat & Mass, Aerospace Dynamics (441), Propulsion(452)	1st semester Jr's Computational Mech II (new course) Compressible(311) & Aerodyn(312) are out of sequence repeats
S11	2nd semester Sr's Design Aero vehicles 436 Design Space vehicles 437	2nd semester Jr's Aerospace Materials – new course Aerolab I – new course Propulsion(452) out of sequence, repeat
F11		1st semester Sr's Aircraft Flight Mechanics – new course Aerospace Dynamics(441) - Design Aero vehicles(436) – out of sequence Design Space vehicles(437)- out of sequence
S11		Aerolab II – new course Aero Design II – new course Space Design II – new course Adv. Aerodynamics & Adv. AeroMaterials – new courses Aerospace Controls – 442

Dual Majors?

Students take additional 15 Credits

- Mmae 304 substitutes for Mmae 306?
- Heat & Mass transfer Mmae 322
- Applied Thermo Mmae 321
- Design of Mech Systems Mmae 432
- Design of Therm Systems Mmae 433
- Manuf. Processes Mmae 485

No difference from existing curriculum

Goals for 2012

- Achieve a top 20 national ranking for the AE undergraduate program within 5 years
  - Modernize AE curriculum based on plan developed by faculty during the summer 2007 – (sell the new program to deans)

- Increase AE freshman enrollment growth rate
  - Educate admissions office about Aerospace Engineering opportunities for undergraduates
  - limit aerospace class sizes

- Capitalize on IIT alumni at Boeing
  - IIT should be on Boeing's preferred list of universities
  - Build on momentum from 5-year plan and seek foundation support to develop a top 10 ranked aerospace engineering program (endowed chair, graduate fellowship)

New Course Descriptions

Computational Mechanics I (MMAE 350):
Introduction to computational mechanics.
Solution of nonlinear equations of one variable
Systems of linear equations
Solution of systems of nonlinear equations
Functional approximation (interpolation, regression, curve fitting)
Numerical differentiation and integration
Numerical solution of ordinary differential equations
Eigenvalue problems

Computational Mechanics II:
Introduction to partial differential equations
Finite difference and finite volume methods
Introduction to boundary element methods
Introduction to Galerkin methods
Fundamentals of finite element methods
Applications of finite element methods with COMSOL

Aerospace Materials (materials component of the aerospace program)

The following are components of one or more courses

Principles of minimum weight design

Materials Selection

Advanced Manufacturing Processes

Airframe and Fuselage Materials (Aluminum, Titanium, Composites)

Propulsion Materials (Titanium, Nickel, Intermetallics, Ceramics and Coatings)

Space Vehicle/Satellite Materials (Refractory Metals, Ceramics, Functional Graded Materials, Multi-Functional Structures)

Environmental Degradation in Aerospace Materials.

Non destructive testing of aerospace components

Labs that are envisioned for this course are as follows and can be run as part of MMAE371 as a separate component for aerospace.

Tensile properties of aerospace materials.Materials to be evaluated in these series of tests are considered to be advanced materials of use in aerospace structures. These include advanced aluminum alloys (e.g., aluminum lithium), exotic aerospace alloys for high temperatures (nickel single crystals), ceramics and advanced composites. Tests on these materials would be carried out at room temperature and high temperatures used for these alloys and specialty materials in structures.

Bending properties of aerospace materials. Materials that cannot be tested in tension can be evaluated by using bend tests and determining Modulus of Rupture (MOR). Bending tests can also be used to determine fracture toughness (KIC).

Impact resistance of several of the aerospace materials. These tests would be used to define the effect of rate on degradation of residual strength.

Creep evaluation of high temperature superalloys.

Fatigue of aerospace materials (effect of temperature)

Testing properties of composites. Fiber strength, laminates, student layups.

Non-destructive evaluation of materials for presence of defects (manufacturing) as well as exposure to environment and fatigue damage.

Junior Aerolab

1 credit of lecture, 2 credits lab instruction

Replaces fluid mechanics and heat transfer labs

Topics to be covered:

- Intro to basic data acquisition with Labview
- Basic aircraft instrumentation
  - altimeter – static pressure measurement
  - airspeed – pitot tube in wind tunnel (indicated, true airspeed, calibrated, equivalent)
  - vertical speed – change in static pressure
  - attitude indicator – gyroscope
- Supersonic wind tunnel – shocks, expansion fan
- Lift, drag & pitching moments on three airfoils in a wind tunnel
  - demonstrate effect of aspect ratio on lift-curves
  - measure pressure distributions and compute CL, CD, Cm and compare with force balance measurements
- Propulsion experiments
  - measurement of thrust from a jet
  - measurement of propeller thrust
  - various efficiencies, propulsive, thermal, …

Senior Aerolab

4 credits – replaces MAE 430 (2-6-4)?

Topics to be covered:

- Fundamentals of **dynamic** signal processing (advanced Labview)
- Applications of analog circuits (Op-amps)
  - amplifier, signal addition, low & high pass filters
- Vibrations experiments
- Dynamic GPS experiments (to be designed by Boris)
- Pitching airfoil control in a wind tunnel using dSPACE, Matlab, Simulink
- Experiments that connect with the construction of their senior aircraft model, such as measure C.G., lift & drag coefficients of their aircraft model in a wind tunnel before attempting to fly it. Can they predict its performance?

Flight Mechanics Topics

- Airplane performance
  - Takeoff, rate of climb, time to climb, ceilings
  - Range
  - Endurance
  - Descent & landing
  - Range payload
  - Operating limitations
  - Energy methods for optimal trajectories
- Helicopters and V/STOL aircraft
- Static Stability and Control
  - Longitudinal stability
  - Directional stability
  - Roll stability
- Aircraft Equations of Motion
  - Kinematics and dynamics of airplanes
  - Linearized equations of motion
  - Stability derivatives
- Aircraft Dynamic Response
  - Longitudinal modes of motion
  - Lateral modes of motion
- Aircraft Control Fundamentals
  - Response to control inputs
  - Autopilot design examples

(Controls course will be taken concurrently, so students will have seen root-locus method at least.)

Aero Design I :

Overview of the aircraft design process

Fundamental design considerations:

- Airfoil selection
- Wing geometry selection
- Thurst-to-weight ratio and wing loading

Aircraft performance and optimization

Aircraft sizing from a conceptual sketch

Refined aircraft sizing

Configuration layout

Payload considerations

Propulsion system

Landing gear and susbsystems

Topics in stability and control

Aero Design II:

Aircraft structure - Design options (shell, rib-spar, etc.)

Aircraft design using 3D CAD package (ProE, SolidWorks?)

Demonstration of structural soundness of the design (using built-in analysis capabilities of 3D CAD systems?)

Introduction to SLS machine, "manufacturing" methods available at MMAE

Propulsion systems for small aircraft

Safety...

Comparison with other Curricula

	Ga Tech	Embry Riddle	IIT – current
Fall year 1	Calc I	Calc I	Calc I
	English Comp I	English Comp I	Humanities
	Chemistry	Physics I	Chemistry
	Computer Sci	Intro Computing	Eng. Graphics
	Wellness	Speech & College success	Intro to Prof.
Sp year 1	Calc II	Calc II	Calc II
	English Comp II	Humanities	Humanities
	Intro Physics	Physics II	Physics
	Soc. Sci.	Soc. Sci.	Computer Sci
	Intro Aero Eng	Intro Aero Eng	Mat. Sci.

	Ga Tech	Embry Riddle	IIT – current
Fall year 2	Calc III	Calc III	Calc III
	Intro Physics II	Phys III + Lab	Physics
	Statics	Statics	Mech. Solids I
	Engr. Graphics	Graph Commun.	Hum/SS
	Eng. Materials	Solid Mech.	Hum/SS
Sp year 2	Low Speed Aero	Tech Report Writing	Physics
	Dynamics	Dynamics	Mech. Solids II
	Tech Elec	Fluid Mech	Comp. Mech.
	Econ	Chemistry	Hum/SS
	Differential Eqn	Differential Eqn	Differential Eqn

	Ga Tech	Embry Riddle	IIT – current
Fall year 3	Syst. Dyn & Control	Space Mech.	Dynamics
	Thermo. & Comp. Flow	Aircraft Structures I	Thermodynamics
	Aero Vehicle Perf.	Aerodynamics I + Lab	Fluid Dynamics
	Deformable bodies	Aircraft Stability & Control	
	Tech. Communication	Thermodynamics	
	Circuits & Elec.	Mat. Sci. + Lab	Phys 300 – circuits
		Elec. Eng. + Lab	Hum/SS

	Ga Tech	Embry Riddle	IIT – current
Spring year 3	Aerospace Structures	Aircraft Structures II	Aerostructures
	Flight Dynamics	Aerodynamics II + Lab	Aerodynamics
	Humanities	Elective	IPRO
	Instrumentation & Elec. Lab	Adv. Engr. Math. I	Eng. Materials
	Propulsion		
	Experimental Fluid Dynamics		Compressible flow

	Ga Tech	Embry Riddle	IIT – current
Fall year 4	Humanities	U.L. Elective	Hum/SS
	Aero Design I or Space Design I	L.L. Elective	Aerospace Dynamics
	High Speed Aerodynamics	Tech. Elective	Heat & Mass Transfer
	Structures Lab	Tech. Elective	Tech. Elective
	Soc. Sci.	Propulsion	Propulsion
	Free Elec.	Aero Structures + Lab	
		Aircraft Preliminary Design	
Spring year 4	Aeroelasticity	Aircraft Detail Design	Design Aero Vehicles I
	Aero or Space Design II	Electrical Eng. II	Engr. Measurements
	AE Control Systems Design Lab	Control Systems Analysis & Design	Design Aero Vehicles II IPRO
	Free Elective		Tech Elective

Boeing’s Desired Attributes of an Engineer

- **A good understanding of engineering science fundamentals.**
  - Mathematics (including statistics)
  - Physical and life sciences
  - Information technology (far more than "computer literacy")
- **A good understanding of design and manufacturing processes.**
  - (i.e., understands engineering)
- **A multi-disciplinary, *systems* perspective.**
- **A basic understanding of the *context* in which engineering is practiced.**
  - Economics (including business practices)
  - History
  - The environment
  - Customer and societal needs
- **Good communication skills.**
  - Written, oral, graphic and listening
- **High ethical standards.**
- **An ability to think both critically and creatively - independently and cooperatively.**
- **Flexibility. The ability and self-confidence to adapt to rapid or major change.**
- **Curiosity and a desire to learn for life.**
- **A profound understanding of the importance of teamwork.**
- **Note:** This is a list of basic, durable *attributes* into which can be mapped specific *skills* reflecting the diversity of the overall engineering environment in which we in professional practice operate. In specifying desired attributes (i.e., desired outcomes of the *educational process*), we avoid specifying *how* a given university goes about meeting industry needs. Curriculum development is viewed as a university task to be done in cooperation with their "customers," and in recognition of their own local resources and constraints. Industry, as an important customer, must be an active partner in this process.