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A RETROSPECTIVE LOOK AT AEROSPACE SYSTEM DESIGN INSTRUCTION AT THE UNIVERSITY OF MICHIGAN

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Abstract

A course in aerospace system design has been offered at the University of Michigan every year for the past 26 years. In 1946 two precursors to this aspect of aerospace education were initiated in the Department of Aerospace Engineering: a major research effort in the High Altitude Engineering Laboratory and the offering of a graduate academic degree in the so-called Guided Missiles Program. The impetus for a course in aerospace system design grew out of these activities and the first students were taught by the late Professor Wilbur C. Nelson in 1965. From the beginning the format of the course was a one-project team effort with student management of the design process a key component. A total of thirty five projects have been completed to date. During the last eight years the effort was considerably enhanced by the sponsorship of the NASA/USRA Advanced Design Program.

Origins of Aerospace System Design at UM

Two major programs were started in 1946 just after the end of World War II in the then Department of Aeronautical Engineering at the University of Michigan which had a major influence on the eventual teaching of aerospace system design. One was the High Altitude Engineering Laboratory which specialized in upper atmosphere research using sounding rockets and balloons and the other was the Guided Missiles Program leading to master's degrees in aeronautical engineering and instrumentation engineering for military officers.

Some of the earliest high altitude experiments were done on captured German V2 rockets launched at the White Sands Missile Range. Later Nike-Cajun two stage solid-propellant rockets were developed for extensive International Geophysical Year studies and in the remaining years of the program, which spanned about 30 years, a variety of sounding rockets were used. Rocket launches were carried out from regular military and NASA launching sites and from a variety of other points around the world including Guam, Fort Churchill on Hudson Bay, and shipboard launchings in the North Atlantic and North and South Pacific. The successor to this activity is the Space Physics Research Laboratory in the Department of Atmospheric, Oceanic, and Space Science, a new department which was created in the 1970's. Some faculty in this laboratory are still associated with the Department of Aerospace Engineering. For a short time we even had our own launching site on the Keweenau Peninsula on Lake Superior in the Upper Peninsula of Michigan. Several rockets were launched in the late 1960's and early 1970's from that site.

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You shall note the influence of this program on the aerospace system design projects in the early years of the course. Many of the early projects reflect the experience of the faculty and staff in upper atmospheric research.

The Guided Missile Program was a two calender year academic program leading to two master's degrees - one in Aeronautical Engineering and one in Instrumentation Engineering. New courses in rocket propulsion, high speed aerodynamics, structural mechanics, and instrumentation and control engineering were developed for this program and dozens of officers from the Air Force and other military services passed through as well as many civilian students. Five alumni of this program were selected as astronauts. Many graduates from this program have and continue to play major roles in both the military and civilian space programs.

The many courses developed for this program set the stage for major activities in space related subjects, but one course in particular whetted the appetite for aerospace system design. A seminar course offered by the late Professor Wilbur C. Nelson as part of Guided Missiles Program featured high-level personnel from government and industry who would describe in detail the many missile programs then underway. The course was, in fact, classified, that is, you needed a security clearance of at least Secret to attend. (Imagine trying to do that today.) Inevitably presentations of the many space concepts speculated on by the Germans were part of the course and were presented by the German scientists and engineers who were brought to this country after the War. As the years went on space topics became a larger part of the seminar series.

After the early unmanned and manned missions in space by both the USSR and the USA, the material for a regular course, not classified, became available. The first course in aerospace system design was offered in the spring 1965 by Professor Nelson and was taught by him 19 times before his retirement in 1976. Professor Harm Buning took over in 1977 and eventually took part in the initial discussions with NASA and USRA which led to the participation of Michigan in the Advanced Space Design Pilot Program in 1985 and the full-fledged program in 1987. Michigan still enjoys the NASA/USRA support through the current academic year. Professor Joe G. Eisley, who has taught a parallel course in computer aided design for several years, will guide future students in the Aerospace System Design course as Professor Buning is retiring this year.

The current project is a mission to the moon of Mars called Phobos. The class will produce a conceptual design of a system to allow the manned exploration and extraction of water from Phobos. The design of the vehicle will include propulsion, orbital and interplanetary trajectories and operations, power, communications, planetary science of Mars and Phobos, and life support. Emphasis will be placed upon the propulsion, life support, and human factors necessary for a long duration mission.

The Format and Output of the Course

From its inception the course adopted the format of a single project with the students divided into subsystem teams. One student is chosen as project manager and another as assistant project manager. Currently this is done by election by the students enrolled in the course after those who seek the job make a short presentation on their particular qualifications. The rest of the students are divided into small teams of three to five persons each with a designated team leader. Each subsystem team's responsibilities is carefully outlined according to function depending on the project. Some are based on technical disciplines, such as propulsion, structures, etc., and others on functional lines such as mission analysis, life support systems, etc. After appropriate subsystem team responsibilities are defined each student is asked to indicate a first, second, and third choice and every effort is made to give the students one of their higher choices. Each team communicates its progress via weekly memoranda that are available to the whole group. The project manager and assistant manager are responsible for seeing that the teams interact and that the work proceeds in an integrated and coordinated manner.

The output of the course consists of three parts: the final report, a scale model of the design, and a formal oral presentation. These three modes of expression bring out many capabilities and talents not found and expressed by the students in the regular courses and we are often pleasantly surprised by which students excel in preparing these presentations.

The first product of the course is a final report, of professional quality. The purpose is to bring to bear upon a specific space mission all the knowledge possible that the students have learned in their studies in other courses and to integrate this into a defensible mission analysis and a workable spacecraft configuration. Some material is new to the team members and must be absorbed in the real time reading of the literature. Technical details are carried as far as time permits. This usually means that enough aerodynamic (if applicable), propulsive, structural, and control analysis is done to size the components and give first order weight and performance estimates.

Industry and government speakers contribute to the course and critique the final report. In the first few years the final report was completed and printed and a public presentation was offered at the end of the term. In more recent years the report material is completed by the last day of class. An ad hoc committee, with representatives from each of the subsystems is responsible for the coordination and preparation of a reproducible copy of the final report at that time.

We have been fortunate to always have had a group of students with sufficient dexterity and experience to create a physical three dimensional scale model of the design. They form an ad hoc committee which, toward the later part of the semester, spends considerable time on this task. The rate of its taking shape increases exponentially toward the end of the semester. It is traditionally unveiled during the final presentation, often still exuding the spell of mode glue!

The third course requirement is the final oral presentation, usually on the Monday evening of the last week of classes. It is a formal affair of major significance. Family, friends, students and faculty, and industry and NASA personnel are invited. Audiences are measured in the hundreds.

The presentations meet the standards of any professional meeting we have ever attended. In fact, we note that presentation at many professional meetings do not measure up to these standards. One of the incentives for a good performance is that this is also a practice for the presentation at the USRA Advanced Design Program Summer Conference.

Goals of the Course

From the instructional point of view there are several goals in design courses which differ from those in other courses. Among them are to

(1) Learn to deal with open ended problems
(2) Use and integrate knowledge from previous courses
(3) Learn the design process
(4) Become acquainted with the tools of design
(5) Experience teamwork in problem solving
(6) Develop oral and written communication skills

Trying to meet these goals can be very frustrating. Students must learn to glean quickly needed information including areas in which they have not studied. They must learn to make reasonable decisions with insufficient detailed knowledge but with a maximum of common sense. This has the effect of a) illustrating the value of basic research, b) emphasizing that this basic research should strive to give answers to anticipated questions, and c) that the results of work should be in a form that can be understood by engineers (without Phd's). We have been told by students and other faculty that the course has often inspired students to go on to graduate study. Apparently they learn what they like most in engineering and now realize they need to know more about it. This is similar to what co-op students often say about their work experience.

In addition the course in aerospace system design intends to arouse interest in the use of space and to develop a final report which is technically correct and sophisticated enough to be useful to NASA and other agencies interested in space.

It is not possible in a one semester course to meet all these goals as well as we might wish, but we do manage to meet a number of them. Just what the design process is and how you go about teaching it is, perhaps, the most nebulous part; nevertheless, the experience of having to go through all the steps in producing a final product, even if it is only a report, does provide some realistic understanding of the process.

Summary of University of Michigan Projects

All 35 projects are listed at the end of this paper. Many of the first 19 projects, under the direction of Professor Wilbur C. Nelson, reflected the influence of the High Altitude Laboratory and dealt with environmental measurements on earth and elsewhere in the solar system. The next several projects, under the supervision of Professor Buning, dealt largely with manned space flight vehicles. Professor Buning spent several summers and a sabbatical at the Johnson Space Center and had instructed many of the Gemini and Apollo astronauts in orbital mechanics.

The last 8 projects have been supported by the NASA/USRA Advanced Design Program and have dealt largely with manned vehicles for Martian or Lunar exploration or space station operations. These are shown in bold faced type in the listing. The second of these, KEPLER, was chosen by USRA for a presentation to the

NASA chief administrator, then James Beggs, as representative of the NASA/USRA program. The most recent project, MEDSAT, was an earth observing satellite for monitoring environmental conditions conducive to the occurrence of malaria. It was done in cooperation with the Space Physics Research Laboratory and was, in a sense, a return to the roots of the course as influenced by the High Altitude Laboratory.

Value of Support from NASA/USRA

The eight projects supported by the NASA/USRA Advanced Design Program have benefited in a variety of ways. The ability to put a teaching assistant at work preparing material for the course the term before the course is conducted allows a much faster start and ultimately a much more sophisticated and complete design project. In fact we organize the course in the fall term before the students enroll in the winter term. The project is selected in the fall and the teaching assistant collects and organizes resource material. Meetings of the potential class members in November allow us to present the project and identify the project manager and other team leaders and to divide the students into teams. The work of the teaching assistant in gathering and preparing background material allows the project leaders to present a plan of action on the first day of class.

The availability of NASA information and personnel greatly enhanced the technical quality of the projects. The active support of a NASA center, in our case the Lewis Research Center, adds a further dimension. In addition to the support they send to the campus, a visit to Lewis just past the mid term of the course proves a popular field trip and an opportunity to present a progress report. The oral report (with appropriate transparencies in true NASA tradition) is critiqued by NASA personnel. The incentive to the students to prepare an accurate and responsible report to be presented to professional aerospace personnel is great.

The Advanced Design Program Summer Conference adds a tremendous lift to the course. The opportunity to meet with and hear presentations from students at peer institutions and to present their project before them is an exceptional opportunity. Certainly the team leaders and some of the other students who hope to attend, but even those students who have no thoughts of attending, are caught up in the excitement of preparing a project which stands up to such scrutiny.

The influence of the course on the students extends well outside the ones enrolled in the course. We have several design courses and less than half of our students (40 to 50 each year out of about 120 graduates) take this course but we hear of students not in the course being caught up in the excitement of it. This course has been used as a model for other courses in the University. The Department of Atmospheric, Oceanic, and Space Sciences is offering a similar course in their graduate program with participation by students and faculty from Aerospace Engineering.

The support from USRA has provided encouragement and support for the faculty who teach design. Design is not the most prestigious or rewarded activity of faculty. While the support in dollars is small when compared to research support, the fact that it exists lends credibility to the instructor and the activity. And while relatively small in dollars it provides benefits which turn a good learning experience into a great one. The teaching assistant support, access to NASA personnel and information sources, travel to the NASA center, supplies for preparing and publishing a report, and support for travel to the Summer Conference all make this a premier course in our undergraduate program.

Listing of Projects

POSSUM: Polar Orbiting Satellite System - University of Michigan. Meteorological observation and weather forecasting. June 1965.

PLUMMET: Penetrating Laboratory of the University of Michigan for Martian Environmental Testing. Mars hard lander sent to measure atmosphere. December 1965.

UPROAR: University of Michigan Proposed Range Operation for Atmospheric Research. Plan for sounding rocket range on Keweenau peninsula. April 1966.

MEDIUM: Meteorological Data Integrator - University of Michigan. Two polar orbiting satellites for long term weather prediction. December 1966.

SPECTRUM: Solar probe to measure magnetic field of the sun. April 1967.

STRATUM: Polar orbiting upper atmosphere measurement. December 1967.

MISSAC: Michigan Instructional Satellite for South American Countries. Geostationary over the Pacific for communications. April 1968.

OBSERVER: Remote sensing of earth's surface for natural resource management. December 1968.

UMPIRE: University of Michigan Probe for Interplanetary Research and Exploration. Jupiter fly-by probe. April 1969.

LINUS: Lunar far side communication satellite. December 1969.

SCANNER: Satellite Communications and Aircraft Navigation for the North Atlantic Region. Geostationary over the Atlantic for navigation. April 1970.

REMUS: Remote Manipulators for Use in Space. System for use in place of EVA from Skylab. December 1970.

MEDUSA: Michigan Educational and Utility Satellite for Alaska. Geostationary over the Pacific for communications. April 1971.

SCOPE: Satellite for Carbon Monoxide Pollution Evaluation. Polar orbiting for atmospheric research. April 1972.

OMAR: Ozone Monitoring and Research. Polar orbit, sun synchronous for ozone layer study. April 1973.

RODAN: Test Satellite for Satellite Solar Power Station Concepts. Two satellites in station keeping orbits. December 1973.

SPIDAR: Solar Powered Ion Driven Asteroid Belt Research. Testbed for ion thruster system. April 1974.

MERMAIDS: Marine Environmental Research. Measure ocean color and surface temperature. April 1975.

NAVITRACS: North American Vehicle Tracking and Communication System. Railroad stock movement monitoring system. April 1976.

LITSTAR: Lighter that air high altitude stationary platform for communication and earth resource observation. April 1977.

OASIS: In orbit shuttle servicer providing solar electric powered, heat rejection, and some attitude control. April 1978.

NEWDUMP: To move highly toxic nuclear wastes into deep space. April 1979.

GENESIS: A Space Technology Evaluation Platform. A first step permanent space station. April 1980.

EXODUS: The Next Step. A new design for a permanent space station. April 1981.

COBRA: Craft for Orbital Based Roving Activities. Two man vehicle to be used from a space station. April 1982.

LO*STAR: Low Orbit Space Transformation Assist Rocket. Vehicle to transport from low earth orbit to higher orbits.

PEGASUS: LEO to GEO orbit transfer vehicle maintained at a space station. April 1984.

The following projects were supported by the NASA/USRA Advanced Design Program.

LUSTAR: Lunar Space Transport with Aero-assisted Return. Low earth orbit to lunar orbit and return to low earth orbit. April 1985.

KEPLER: Manned transfer vehicle from earth to mars. April 1986.

CAMELOT: Earth to Mars and return personnel transport in a circulating orbit. April 1987.

CAMELOT II: Continuation and refinement of Camelot including component design. April 1988.

ARGO: Transport vehicle from low earth orbit to geosynchronous orbit and return. April 1989.

EGRESS: Assured crew return vehicle from a space station. April 1990.

MEDSAT: Earth observing satellite for monitoring malaria infestation. April 1991.

UM-HAUL: Reusable transportation system between lunar orbit and lunar surface. April 1991.