

PROJECT FALCON BASE: A FRESHMAN ENGINEERING EXPERIENCE

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ABSTRACT

A new freshman course is currently being developed and taught on a pilot basis to approximately 40 cadets per semester at the United States Air Force Academy. The purpose of the course is to better address the educational outcomes desired in Academy graduates. Presented as an engineering experience instead of a sequence of classroom lectures, the pedagogical setting for student teams is an Air Force System Program Office responsible for design and deployment of a manned research base on Mars. Instruction follows the Socratic method wherein students are guided to identify the relevant tasks and engineering requirements pertinent to the plan. Traditional instruction is used sparingly to present specific tools and concepts. Quantitative assessment data from the first offering are encouraging because a significant improvement in the students' ability to frame and resolve ill-defined problems (a priority outcome) has been measured. Qualitative assessment-findings show that the students learned important engineering fundamentals, liked the course and enjoyed the Mars scenario, developed an understanding and appreciation for engineering as an interdisciplinary process, and developed confidence in their ability to make decisions and assumptions needed to obtain results. The course, the assessment plan, and preliminary findings are presented in this paper.

I. INTRODUCTION

Background

Engineering 110Z (Engr-110Z), a new freshman engineering course, is a 3-year experiment underway at the United States Air Force Academy (USAF). The need for and goals of Engr-110Z stem from the Academy's mission statement: To Develop and Inspire Air and Space Leaders with Vision for Tomorrow. Consistent with the mission statement, members of the faculty recently defined a set of complementary educational outcomes (Appendix-A) desired in Academy graduates¹. While Engr-110Z addresses all outcomes, priority is given to: framing and resolving ill-defined problems; intellectual curiosity; fundamental engineering knowledge; and professional communication skills in written, oral and graphical formats. Since Engr-110Z is an experiment, a special assessment plan has been designed to determine how well the outcomes are being met.

In contrast to the traditional teacher-centered² approach in engineering courses, the student-centered²⁻⁴ approach replaces the pre-planned lectures with a project requiring students to design and build a device like a human-powered pump, a wind turbine, or an electronic apparatus. The instructor becomes a mentor who guides the students through the design and construction process. In this way, the students acquire ownership over their products, and they learn that engineering is an interdisciplinary process, not just a collection of concepts, equations and facts. Overall, the student-centered approach instills confidence and a willingness to make choices and assumptions needed to obtain results. Furthermore, it teaches students that teamwork is essential in successful engineering endeavors.



Service in the Air Force, and the USAFA academic core impose two pedagogical requirements on engineering courses at the Academy. First, as future officers in the Air Force, USAFA cadets are more likely to work on systems than on individual devices. Therefore, the students in Engr-110Z are given a multifaceted systems-design problem instead of a device-specific design. Moreover, many Academy graduates will participate in and have responsibility for a variety of complex Air Force programs that often involve interrelated activities involving the disciplines of engineering, economics, politics, sociology, medicine and psychology, and law. Therefore, USAFA graduates must possess an integrated body of fundamental knowledge. So the project given in Engr-110Z is selected deliberately to engage the students in numerous integrated technical and non-technical issues: the design and deployment of a manned research base on Mars. The interdisciplinary nature of this project requires the students to interact with many instructors from engineering and social science faculties. Research done by sub-groups meeting with faculty experts, investigations on sub-system components, interactions with cadets in other classes (upper division cadets), and contact with other agencies like the NASA Center for Mars Exploration are all part of course. In this regard, Engr-110Z seeks to be an experience for the students, hence the name, “A Freshman Engineering Experience.”

Second, the USAFA academic core includes basic engineering courses from the five engineering departments. These engineering foundation courses are intended to prepare cadets for their upper-class studies and design projects. Some cadets, however, fail to recognize the importance of these courses especially when they are not in the cadet’s major field of study. Also, many cadets fail to recognize the principles common to each engineering discipline. Placed early in their USAFA academic program, the interdisciplinary student-centered approach of Engr-110Z seeks to motivate cadets to develop an appreciation for and an improved interest in engineering and their remaining core-studies.

Approach

Engr-110Z is being developed and implemented as a three-year pilot course with two sections being taught each semester. The students in each section are selected randomly by the USAFA Registrar from the annual pool of freshman cadets. The three-year trial period will provide adequate data to support the assessment plan. The Engr-110Z experience has three parts: development and implementation of the course as explained in Sections II and III; development, administration and evaluation of an assessment plan as explained in Section IV; development of a program to train new Engr-110Z instructors. Development of the instructor training program begins in July, 1996, and will be implemented the following year.

II. SCENARIO

Small cadet teams address problems associated with the design and deployment of a manned research base on Mars. The scenario models an Air Force System Program Office (SPO) called Project Falcon Base. The name of a famous 19th century astronomer, Giovanni V. Schiaparelli (1877)⁶, is used to identify the SPO director, “General Schiaparelli.” The mission statement (the task given to the cadets; see Appendix B), the directives (the assignments; see example in Appendix C), and progress review assignments come from the SPO director. From the beginning, the cadets are responsible for developing the Mars mission-plan. They are required to organize themselves into appropriate working groups, to identify the major and minor tasks, to build a plan of activity and action items, to define and request guidance about subjects for which they lack background or understanding, and to meet the reporting deadlines as directed by the SPO. Their final product is



a written technical report describing the mission plan accompanied by an oral briefing to senior faculty members.

In this scenario, USAFA faculty members function as senior SPO engineers and managers who guide the cadet teams. The instruction follows a Socratic method. Theory, technical details and other related issues are revealed through a combination of leading questions, special topic presentations by “expert” consultants (faculty and guest lecturers), and cadet-research efforts. This approach gives students the opportunity to experience the satisfaction of self-discovery while also providing them ownership over the outcomes. After receiving an inquiry or request for help from the cadets, an expert provides information needed to do the job. However, the expert does not “tell all!” Instead, the expert works diligently to lead the students to the understanding they seek. Also, the expert must not swamp the students with numerous facts and formulas. Rather, the expert presents the technical information in a “just-in-time” manner so that the students gain understanding of the concepts while simultaneously learning how to use them. To reinforce confidence, provoke the use of common sense, and instill a willingness to make decisions, the cadets are usually presented open-ended problems that require them to make estimates for unspecified quantities. For example, when recently discussing storable energy forms, the students were asked to determine the kinetic energy of the USAFA Cadet Wing while it was marching. Then they had to equate this energy to food items of their choice that contained equivalent energy.

Freshman cadets have few liberties at the Academy, so planning and good communication are established early. To help meet this need, tool-day classes provide training on the use of the application software on the USAFA Network (spreadsheets, slide-presentation-makers, text editors and E-Mail), and on using the World-Wide-Web. Skill in using these tools is strengthened by SPO directives. For instance, in a recent directive (Appendix C), Gen Schiaparelli asked if the lunar space suits used by the astronauts in Project Apollo could also be used in Project Falcon Base. The cadets were given no guidance on how to approach this directive; they were told only to prepare a response by a certain date. The exercise required the cadets to identify requirements for survival and mobility on Mars, to perform and organize research, to prepare their recommendation for oral presentation, and to make the presentation to two senior engineering professors.

The Mars research base scenario gives the cadets opportunities to address many technical and non-technical issues. Once identified, the technical issues group nicely into the three broad categories of travel, living, and power production. The non-technical issues are general and encompass historical points learned in discussing the Manhattan project, Project Apollo, and Colonial Jamestown. Along with human behavior, political, social and economic issues, legal and ethical issues that affect space-exploration and the use of nuclear devices in space are also discussed. An example requiring the cadets to consider important non-technical issues is the following question taken from the first-term final examination:

At this time, scientists from other countries are being considered for participation in the initial Falcon Base research team. Sheik (Dr.) Abdul Rhammani from the Saudi Arabian Center of Petroleum Research, Dr. Judith Spieglemen from the Israel Geological Institute, and Prof. Annibel Zirkofsvich from the Bosnian Center for Infectious Disease Studies are three foreign nationals being considered for the mission. What impact on mission planning could their participation in the program create?

III. FOUNDATIONS IN ENGINEERING



The three broad categories, travel, living, and power production, define a framework upon which cornerstone fundamentals are developed. Travel embodies fundamentals in propulsion, flight mechanics and orbital mechanics, and the basic concepts of forces and motion. Living includes the architecture (size, shape and layout), structural integrity of the Falcon Base habitat, life support, and site selection on Mars. Power production introduces basic concepts in thermodynamics along with the three modes of heat transfer, and an introduction to a variety of processes for the generation of electrical power. Somewhat simplified, these concepts are presented as *Science-Things* and *Engineering-Things*, the distinction being that *Engineering-Things* are the manmade devices and process built on the basis of the laws of nature (the *Science-Things*) to accomplish specific tasks.

A propulsion exercise is described here to show the pedagogy of Engr-110Z. In the travel category, the cadets identified the need to understand rocket propulsion as a requirement. In response to their inquiry, a propulsion expert gave them a project instead of a lecture on propulsion fundamentals. Divided into three or four member teams, the expert tasked the cadets to design and build a rocket constructed from a plastic soda pop bottle to be tested (launched) about two weeks later. Water pressurized to a level prescribed by each cadet team would be the rocket propellant. Notice that at this point, the cadets knew nothing more about propulsion than they did when they asked for help. Indeed, they now had more to do.

The help they sought came from their guided, “learning-through-design” efforts. Simply glueing pieces together to make a rocket was unacceptable. Starting from first principles, the cadet teams had to develop theoretical models to determine estimates for the initial conditions and optimum performance of their rockets. Modeling rocket propulsion begins with Newton’s 2nd Law of motion applied to an accelerating body with unsteady mass flow, quite a formidable undertaking for freshmen. However, using the Socratic method, experts led them to recognize the main ingredients: mass and energy conservation, and the relationship between forces and momentum, while all the time applying these concepts to their rocket models. In place of calculus, integration was done numerically using difference relationships and a computer spreadsheet.

Building and testing the rockets followed the modeling. On launch-day, the students had to tell the range-officers the initial conditions for their rockets (e.g., nozzle size, water level, bottle pressure), as they had previously determined from their theoretical models. After launching their rockets and observing the flights, they were encouraged to make changes to their spreadsheet models to see if more accurate predictions could be obtained. Closure on rocket propulsion fundamentals came in the class following the tests. The experts used a workshop format to engage the cadets in a discussion on results, factors influencing performance, and factors omitted from the modeling. Lastly, the experts used this meeting to introduce new and relevant factors such as aerodynamic stability, absolute velocity, launch irregularities, the role of fins, the relationship between center of mass and the aerodynamic center for flight systems, and why a cloud appeared in the bottle at the end of each flight.

Several types of open-ended problems are used to present other fundamentals. Trajectory problems are used to present basic concepts in flight and orbital mechanics. Laboratory studies on the performance of a turbocharged Chevrolet 454 cubic inch engine, and wind turbine experiments performed in a low speed wind tunnel are used to learn about power production and efficiency. From research on other processes (e.g., solar, nuclear, MHD, power cells), the cadet teams prepare a recommendation for the production of power at Falcon Base. And in the living category, the cadets investigate and prescribe the architectural requirements for the Falcon Base habitat as well as determining facility requirements and site selection, all fundamental elements of civil engineering. The question shown below is taken from the first term final examination:



One of the structure proposals for Falcon Base windows contains a 1.0 ft-diameter tempered window securely held by an aluminum frame. The frame is secured to the structure with aluminum bolts that have a yield strength of 70 kpsi. For a nominal atmospheric pressure on Mars of 0.1 psi., determine a bolt pattern, size and shape, that will safely hold the window frames in place.

In summary, to the cadets, the fundamental concepts presented in Engr-110Z appear to be determined by them, but in reality, the course designers have made these determinations ahead of time. Using the SPO mission directive, follow-up tasks, and inquiries by the SPO, the Engr-110Z instructors ensure that the desired foundations in engineering are covered in two broad categories: science knowledge (*Science-Things*) and engineering knowledge (*Engineeirng-Things*). Within the category of science knowledge, cadets develop an understanding of Newton's Laws of motion, the first and second laws of thermodynamics, and foundations in electrical power. By necessity, the application to Falcon Base generates treatment of concepts in heat transfer, energy storage and transfer mechanisms, electrical circuits, force, momentum, and mechanical stress. The value of the "just-in-time" approach is that students learn the fundamentals to address an immediate engineering need. As a result, they are more apt to retain the knowledge. The challenge for the Engr-110Z student is to understand the *Science-Things* and then learn how to design the *Engineering-Things* to meet task requirements.

IV. INTEGRATED ASSESSMENT PLAN

An assessment plan is essential in Engr-110Z. Developed by experts in educational psychology and academic instructional design, the plan⁷ is implemented with minimum intrusion. The plan incorporates assessment of the Academy-desired educational outcomes with course-specific knowledge of fundamentals. Like the course, no assessment plan existed at the onset. The course designers had to decide the educational outcomes to target for Engr-110Z, and the assesement experts then had to pick the appropriate assessment instruments. Based on a review of known cognitive assessment methods used in other undergraduate engineering programs⁸, the instruments shown in Table-1 are being used to assess Engr-110Z. Note that while the paradigm for Engr-110Z naturally includes all USAFA educational outcomes, only the priority ones, as shown below, are part of the assessment plan.

Framing and Resolving Ill-Defined Problems

The Reflective Judgment Exercise⁹ (RJE) is the primary instrument used to assess performance for framing and resolving ill-defined problems, the highest priority educational outcome for Engr-110Z. Two RJE's are administered, one at the beginning and one at the end of the course (see Appendix D). Each RJE has two parts. In the first part, the student is given an ill-defined problem scenario containing overlapping sets of incomplete information. From these data, students are required to make a decision based on their ability to extract information from the data sets. In the second part, the students are required to reflect upon their decisions, indicate a position of confidence, identify how confidence could be improved if more information were available, and identify the information needed for improvement.

Results for the first term application of the RJE's that were given to both the test and control groups are presented in Table 2⁷. The Engr-110Z students in sections (A) and (B) are the test group, and an equivalent number of students in two sections of EM-120* are the control group.

TABLE 1. INTEGRATED ASSESSMENT MEASURES

ED. OUTCOMES	INSTRUMENT	ED. OUTCOMES	INSTRUMENT
1. Integrated Fundamental Knowledge (priority outcome)	Student Self-Reports Concept Maps Faculty Observations Exam Questions	5. Teamwork	Student Self-Reports Faculty Observations
2. Framing & Resolving Ill-Defined Problems (highest priority outcome)	Reflective Jugement Exercise Student Self-Reports Exam Questions	6. Intellectual Curiosity (priority outcome)	Student Self-Reports Faculty Observations Exam Questions
3. Communication Skills (priority target)	Oral Briefings Written Reports Student Self-Reports Exam Questions Faculty Observations	7. Officership and A Military Profession	Student Self-Reports Faculty Observations Concept Maps Exam Questions
4. Independent Learners	Student Self-Reports Faculty Observations Concept Maps Exam Questions		

Grading RJE's is subjective. Here, a scale of 1 (unsatisfactory) to 5 (excellent) is used. With 3 representing a satisfactory level, the mean score initially for both groups (test and control) is nominally 2. About 17 weeks later, the mean score for the Engr-110Z groups advanced to about 2.9, whereas for the control group, no statistically significant advancement occurred. To be impartial, both sets of RJE's were administered by a USAFA educational psychologist, randomly stacked into a single bundle, and sent to an outside professional consultant⁹ for evaluation. The consultant had no prior knowledge about the student or group identification shown in Table 2.

Table 2. Reflective Judgment Exercise Results: Fall-1995

	August 1995		December 1995	
Section	Number Score	Mean	Number Score	Mean
Engr-110Z (Sec. A)	20	2.05	17	3.00
Engr-110Z (Sec. B)	22	2.00	18	2.80
EM-120 (Sec. A)	19	2.16	12	2.25
EM-120 (Sec. B)	20	2.30	10	2.50

* EM-120, Engineering Mechanics 120, is a sophomore USAFA core course in statics and strength of materials. Two sections of it are used to form the control group for the RJE because no comparable group of freshman cadets could be used.

Student Self-Reports contain comments indicating overall positive attitudes and confidence in coping with ill-defined problems and to illustrate, a few comments are shown here:

I think I've gotten better at that (ill-defined problems) too....in the beginning, I wasn't very good at solving ill-defined problems. I think I improved upon that as I went through it (Engr-110Z).

This course more or less goes against everything most of us learned in high school. Usually high school kids get the right answer and if you don't get it, you're wrong. It's simply that way. There's one way to start and one way to finish (an assignment), and there's no different paths to choose. I don't think the real world is that way. I think the real world is full of ill-defined problems, and therefore, I think the course was beneficial...it helped do that.

The homework is different....it's mainly ill-defined problems. I wasn't expecting this and it made me nervous early on, but I have been working at it and getting good results.

This class makes me think more than other classes do. There's no answer in the book. There is no book!

Intellectual Curiosity

In spite of its appeal as a desirable character attribute, intellectual curiosity is a difficult educational outcome to assess because it is more akin to behavior than performance. An important challenge confronting assessment efforts is to distinguish student performance from student behavior. Even though both are mutually influential, performance is generally easier to measure and has been accomplished historically using a variety of testing techniques. As student behavior is strongly attitudinal, its measurement is primarily subjective and difficult to assess. If a student does something not explicitly asked, did the student do it because of intellectual curiosity or because of a perceived requirement? At best, the instruments available to measure this characteristic are marginal. Thus for the most significant finding for Engr110Z is that a clear meaning of intellectual curiosity as it pertains to the cadets is missing. Work is underway to correct this situation.

Integrated Body of Fundamental Knowledge

Cadet responses to task-assignments, oral questions inherent in the Socratic method, concept maps and examination questions are used to obtain both qualitative and quantitative evaluations on the cadets' understanding of basic engineering concepts. Overall, the results indicate that the Engr-110Z students understand the broad fundamental concepts introduced in the course. Considered with the other examples, the problems below show the breadth of coverage.

After listening to your briefings on the space suits, it is evident that Martian atmospheric pressure is an important design consideration. Col Smith has noted that to provide the research team with complete exploration of the Martian surface, the suits must be designed to safely handle the pressure variations. At one extreme, Olympus Mons, a Martian volcano nearly 600 km in diameter and over 26 km high, is the highest mountain known in the solar system. For the other extreme, Valles Marineris is a Martian canyon, like the Grand Canyon on Earth, only Valles Marineris is over 3000 km long and up to 8 km deep. Briefly describe a proper method to estimate the pressure range the suits need to sustain for safe and total exploration of Mars.

A contractor has proposed to Gen Schiaparelli to use Sillatex for the roofing material on Falcon Base. Sillatex is a proprietary compound developed by the contractor, and it has a thermal



conductivity of 0.038 W/m-K. The contractor claims the roof need only be 20 cm thick for adequate thermal protection. Is this claim reasonable? By neglecting radiation, one approach to determining the effectiveness of the Sillatex roofing is to apply an energy balance to a section of the roof. Here, the energy conducted through the Sillatex is equal to the energy convected from the outer surface to the Martian environment. This approach allows determination of the outer surface roof-temperature which, in turn, can be compared to the Martian atmospheric temperature. For the Martian environment, a nominal value for the convective heat transfer coefficient is 150 W/m²-K

Earlier, we investigated concepts for sounding rockets. We have recently learned some sounding rockets will carry sensitive electronic instruments that can withstand an acceleration of only 5.5 Martian g's before they are damaged. On Earth, the sounding rocket with its instrument payload weighs 200 N. What is the maximum thrust allowed for a launch on Mars whereby the equipment will not fail ?

The down side to exposing the cadets to a broad body of knowledge in a single course is that cadets do not get the same level of practice with topical homework problems as is usually found in the engineering classroom. As a result their skill in this area is more limited. Discussions are under way to determine if this is a concern for Engr110Z and if it is, what corrections should be made.

Communication Skills

Effective communication skills is an educational outcome that can be assessed directly by evaluating the cadets' performance in writing and speaking. Engr-110Z also includes the generation and use of graphs as part of this outcome. At the Academy cadets have many opportunities to make oral presentations to groups of people. Within the academic program, cadets are required to prepare written and oral presentations in many courses, so a lack of practice is not an issue. In Engr-110Z, preparing point papers, technical reports and memoranda are objectives for written communication skills. Technical briefings and verbal progress reports are objectives for oral communication skills. Presenting technical data in charts and concept maps depicting proper association of interrelated factors are objectives for graphical skills. Tool-days are used throughout the course to show the cadets how to use computer resources to aid in their communication efforts.

Thus far, communication skills assessment has been qualitative except for a few written assignments. Cadet teams made three presentations during the first course offering. Each was critiqued, but not graded, so quantitative data are unavailable. Accordingly, design of appropriate quantitative instruments for assessing this educational outcome is underway, and it will be used in future course offerings. Nonetheless, the qualitative information obtained from Student-Self-Reports (some are presented below) and faculty interviews indicates strong gains were made, especially with regard to oral communication.

I learned about briefing. I think that there is a difference between presentations and briefings. I never gave a briefing before in high school.

I think that (the briefings) was the best thing I learned to do.

We're kind of forced to use transparencies, which I had never used before in high school, and I used Powerpoint for the first time.

I liked doing presentations. I know we are going to have to do that throughout our Air Force careers and in our lives. I had no idea about the way it was supposed to be done before



this (before Engr-110Z)..... I liked that part a lot.

V. CHALLENGES

Many challenges confront Engr-110Z, but the three primary ones are time, instructor comfort and coordination. Compared to the structured teacher-centered classroom, the Socratic method used in a student-centered environment requires considerably more time to cover equivalent topics. In the student-centered classroom, most of the time is spent on leading students to the information that would otherwise be told to them in a prepared lecture. The challenge for the Engr-110Z designers is to find ways to lessen the “student-leading-time” so that the level of content can be maintained without abandoning use of the Socratic method.

Instructor comfort is somewhat akin to the time-challenge. When observing students struggling with concepts, the overwhelming tendency for the mentor is to switch quickly into the instructor mode and begin telling the students information in the more conventional lecture format. The challenge is to present only the information explicitly asked for by the students, or to lead them to ask for it when they have not.

Coordination is very important when faculty members from different departments are needed in the course. However, this challenge is the easier of the three to solve because it only requires good planning up front, and flexibility to adjust scheduling on very short notice when faculty members suddenly become unavailable. Another aspect of this challenge is to make sure the guest experts understand and are willing to use the Socratic method.

VI. CONCLUSIONS

Engr-110Z is a new freshman engineering course under development at the United States Air Force Academy. The purpose of the course is to better address specific educational outcomes defined by the faculty. The academic scenario in Engr-110Z is that of an Air Force System Program Office, which has responsibility for the design and deployment of a manned research base on Mars. Faculty members become role-models for senior engineers and managers of the SPO who use a Socratic method of instruction to guide students through a variety of engineering tasks. The first year of a three-year development period has been completed, and the significant findings obtained from a professional assessment are:

1. The cadets’ ability to frame and resolve ill-defined problems increased significantly.
2. No conclusive data were obtained to assess intellectual curiosity.
3. On average, cadets’ oral communication skills improved.
4. On average, cadets realize that engineering is an interdisciplinary process.
5. In general, cadets liked the open-ended nature of the course. They were not troubled by a lack of detailed structure or the lack of a textbook.
6. Cadets had mixed opinions on the teamwork activity; some liked it, others did not.
7. Cadets like the SPO scenario associated with the design of a manned research base for Mars.

VII. REFERENCES

1. “United States Air Force Academy Educational Outcomes and Their Assessment: An Integrated Approach,” Educational Outcomes Assessment Working Group, A Presentation at the American Association of Higher



- Education, 10TH Annual Conference on Assessment and Quality, Boston, MA, Jun 13, 1995.
2. Ladesic, J.G. and Hazen, D.C., "A Course Correction for Engineering Education," Viewpoint, *Aerospace America*, May, 1995.
 3. Crawley, E.F., et. al, "Reform of the Aeronautics and Astronautics Curriculum at MIT, *Journal of Engineering Education*, January, 1994. pp. 47-56.
 4. Ettouney, O.M., "A New Method for Integrating Engineering into the Liberal Education on Non-Engineering Undergraduate Students," *Journal of Engineering Education*, Oct, 1994. pp. 349-355.
 5. Vincent Ercolano, "From Sleep to Success 101," *ASEE Prism*, September, 1995, pp. 25-29.
 6. Kieffer, H.H., Jakosky, B.M., and Snyder, C.W., "The Planet Mars: From Antiquity to The Present," *Mars*, The University of Arizona Press, Tucson, AZ, 1992, pp. 1-33.
 7. Marlino, M.R., et. al, "Engr-110-Fall 1995 Cognitive Assessment Report," Feb. 1996: copies available on request from the Center for Educational Excellence, HQ-USAFA/DFE, USAF Academy, CO 80840-5000
 8. Reeves, T.C. and Okey, J., "Alternative Assessment For Constructivist Learning Environments," in B. Wilson *Constructivist Learning Environments*, Educational Technology, Englewood Cliffs, NJ, 1996. pp. 191-202.
 9. Lynch, C.L., Kitchener, K.S. and King, P.M., "Developing Reflective Judgment in The Classroom," A Manual for Faculty in the Department of Behavioral Sciences and Leadership at the United States Air Force Academy, 1994. Copies available from: Reflective Judgment Associates, HCR 75, Box 91, New Concord, KY 42076.

VIII. APPENDICES

Appendix A: USAFA Educational Outcomes

1. Officers who can frame and resolve ill-defined problems.
2. Officers who are intellectually curious.
3. Officers who can communicate effectively.
4. Officers who possess breadth of integrated, fundamental knowledge in the basic sciences, engineering, the humanities, and social sciences, and depth of knowledge in an area of concentration of their choice.
5. Officers who can work effectively with others.
6. Officers who are independent learners.
7. Officers who can apply their knowledge and skills to the unique tasks of the military profession.



Appendix B: The Mission Statement Directive

HQ-AFMC/FBMARS
FALCON BASE SYSTEM PROGRAM OFFICE
WRIGHT-PATTERSON AFB, OH 45431

MEMORANDUM FOR RECORD

DATE: 4 Jan 96
TO: Commander, USAFA Division
FROM: G.V. Schiaparelli, Brig.Gen., USAF
Director, Falcon Base Program Office
RE: USAF S.O.-1496, Mission Statement, Manned Research On Mars

Under DoD Directive 2000, USAF Special Order-1496 establishes the mission statement for a manned research base on Mars. Accordingly, I direct you to begin developing a plan for a manned research mission to Mars to be performed in the year 2000. The duration of the research activity on Mars should be nominally 1 year, but the actual time will be determined by the scope and content of the research identified in your plan. The size of the research landing party will be the minimum number of people needed to guarantee successful completion of the research objectives.

To distinguish the USAFA Division, I have chosen Falcon Base as the name of your project. Our SPO designation is FBMARS, standing for Falcon Base on Mars.

Your plan is to include the technical, social, economic, ethical and legal, political, and health (both physiological and psychological) factors, plus other issues deemed important by your team.

Directive S.O.-1496 is an Air Force initiative. However, the NASA Center for Mars Exploration offers a potential for coupling research interests and activities. Specifically, NASA has a HomePage on the WWW for this center, so please investigate this resource.

For now, membership in the landing party is restricted to US citizens in the US Air Force or NASA. Subject to presidential directives, however, one or two foreign national scientists may be included.

I have a major report due to the congress on 9 May 96. Therefore, your plan must group the numerous issues and activities into a few central tasks thereafter to be perfected by your division during the next 17 weeks. In the interim, I will need status reports from you, as well as answers to specific questions. My staff will

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provide you my requirements as they develop.

My staff and I are available to you for assistance. Good luck.

Appendix C: Lunar Suit Inquiry Directive, A Student Assignment

HQ-AFMC/FBMARS
FALCON BASE SYSTEM PROGRAM OFFICE
WRIGHT-PATTERSON AFB, OH 45431

MEMORANDUM FOR RECORD

DATE: 1 Feb 96
TO: Commander, USAFA Division
FROM: G.V. Schiaparelli, BRIG GEN, USAF
Director, Falcon Base Program Office
RE: (1) Project Planning
(2) Environmental Protection Issues on Mars

My staff informs me that your proposals for the overall Falcon Base Project Plan have been received and are now in review. I anticipate providing your division my recommendations no later than 6 Feb 96.

Providing adequate environmental protection for the research-team members while they move about the Martian surface is a concern that was hotly discussed in yesterdays' staff meeting. Basically, I need to understand if the lunar protection methods developed in Project Apollo are adequate for protecting the Falcon Base research team, or are new methods needed. Please have your division investigate this issue and report back to my office with your findings and recommendations by 12 Feb 96.



Appendix D: The Reflective Judgment Exercises, Pre and Post Applications

Note: Part Two is attached to Pre and Post Parts One.

Part One:

Pre-RJE:

The Commander asked me to put together a maintenance support package for our deployment of two KC-135s to a temporary operating location. When we recently deployed three aircraft, our support package had 30 maintenance personnel and we were able to fly a total of 36 sorties for the two days that we were deployed. Two years ago, we took 16 personnel and five aircraft to Eglin AFB where we flew 40 sorties in the four day we were deployed. Our sister-squadron just returned from a five day trip where they flew ten sorties in the five days

they were deployed, using just five technicians and one aircraft.

The Colonel wants to fly 30 sorties in the three days we are deployed, and use 20 personnel for maintenance support.

How effective do you think we will be during the three-day deployment in meeting the Commander's objective for 30 sorties?

Note: A sortie is a flight-mission.

Support your position by describing how you arrived at your answer.

Part-One.

Post RJE

The Air Force wants to establish new guidelines for survival under desert conditions. Data have been gathered from crash landings that occurred in deserts over the past 30 years. In 1967, four members of a seven man crew survived for 19 days by drinking an average of two quarts of water and ingesting two salt tablets per day. In 1972, all members of a six man crew survived for 14 days by drinking 1.5 quarts of water per day without salt tablets. In 1976, only three members of a nine man crew survived for 17 days despite an allocation of 3 quarts of water per day and an unlimited supply of salt tablets.

A consultant has recommended to the Air Force that it provided for at least 4 quarts of water and four salt tablets per person per day to ensure survival under desert conditions with the expectation of rescue within 14 days.

How effective do you think these allocations would be if you and your seven person crew crashed in the desert and were not rescued for 22 days?

Support your position by describing how you arrived at your answer.

Part-Two:

Student Reflective Judgment Questions

On a scale of one to ten, how certain are you that your answer is correct? (10=Absolute Certainty)

On what do you base your level of confidence?

Does your answer depend on any particular assumptions? What are some of the most important ones?

If you could choose to have one more piece of information, what would that be?

How would that additional information change your original answer?

