A New Path to the Moon

Cadets involved in research at the United States Air Force Academy’s Department of Astronautics have helped uncover the properties of a newly discovered path to the Moon that is more efficient than previously discovered methods.

Trajectories taken by spacecraft on their way to the Moon have typically taken one of the most efficient paths known. This trajectory is named after Walter Hohmann who developed the mathematics behind the trajectory in 1925. As space travel became a reality, this trajectory, or close approximations, has been used extensively to transfer spacecraft from one orbit to another. When lunar missions were designed, the Hohmann transfer method was also applied in order to get to the Moon using the smallest rockets possible (Figure 1).

In the 1960’s, methods were developed that allowed even more efficiency to be gained over the Hohmann transfer scenario by using gravity assists (or swing-bys). These gravity assists are accomplished by flying past a planet or asteroid on the way to the spacecraft’s destination. The gravity assists allow the spacecraft to take some of the energy from the body that it passes in order to increase its own velocity.

However, when traveling from the Earth to the Moon there are no large bodies to swing by. So the traditional Hohmann transfers to the Moon continue to be used in most cases.

Recently, though, a few different efficiency improving methods have been pieced together to form what is called a Ballistic Capture Transfer (BCT). A BCT trajectory uses less fuel than the Hohmann transfer for lunar missions and is shown in Figure 2.

Figure 2 – Ballistic Capture Transfer

In this scenario, a spacecraft fires its engine from a near Earth parking orbit (A) to send it toward the Moon. When it reaches the Moon it uses a gravity assist to propel itself even further away from the Earth (B). As the spacecraft gets further from the Earth the gravitational pull of the Earth slows it down and causes it to return. However, near its furthest point (C) the Sun’s gravitational pull causes the orbit to change shape so that as the spacecraft comes back it follows a path that closely parallels the Moon’s orbit for several days (D).

While the spacecraft is traveling near the Moon at roughly the same velocity, the Moon captures the spacecraft in it’s gravitational pull (E). The spacecraft is then in orbit around the Moon.

This new method is more complex than the Hohmann transfer, but from a fuel perspective it is more efficient. The Hohmann transfer requires the spacecraft engine to fire once at Earth to start its journey, and another engine firing to slow the spacecraft down and enter an orbit around the Moon. This new BCT trajectory still requires the engine to fire at the Earth to begin the transfer, but it approaches the Moon in such a way that the second engine firing is not necessary.

The longer travel time, larger distances from Earth and the added complexities are the trade-off for the improved fuel performance of the BCT. Since this new type of orbit has only been known about since the early 1990’s, not much investigation has gone into it to help understand the various properties of this orbit.

In order to help reduce the complexity problem, over the past few years the Department of Astronautics has been studying this trajectory to help determine its viability as a standard transfer.

Some of the work done to date includes:
1) an investigation into the feasibility of using the BCT for small satellite missions to the Moon, Cadet 1st Class (C1C) Johnston A. Coil
2) an analysis of the effects of engine burn errors for BCT’s, C1C Stephen J. Pinchak
3) an investigation of lunar capture conditions, Earth departure

In this issue:
- Lead article: A New Path to the Moon (pages 1-2)
- Department Research News (page 2-3)
- Publications and Presentations (pages 4-7)
- and several other aspects of BCT trajectories, Dr. Scott Dahlke

Much of this work has been done in the effort to evaluate this trajectory as an option for use on a future USAF Academy small satellite mission. The Department of Astronautics is looking
Department of Behavioral Sciences

During the first half of this year, Aptima, Inc. (Woburn MA), collaborated with faculty and students at USAFA to complete the first in what we hope will be a long series of studies to investigate fundamental human-performance issues in Command and Control (C2) decision making. Our collaboration brings together Aptima researchers, engineers and technologies, with expert faculty and high-quality students from the Behavioral Science and Leadership (DFBL) and Management (DFM) departments at the Academy. Our initial efforts centered on team-performance research using Aptima’s DDD team-in-the-loop simulation as an experimental platform, high quality USAF cadet participants, and innovations in performance assessment in simulation-based experimentation. Our collaborative work has thus far been supported through Aptima’s Phase II SBIR, A System to Enhance Team Decision Making Performance (contract F41624-98-C-6010) and related funding, but has generated AFOSR interest outside the scope of that contract. Over the coming months, Aptima and USAFA will continue to work together under Aptima’s Phase II contract, and hope to acquire additional support to broaden our research scope. This fall, we will also integrate follow-on studies and related research more closely with the curricular goals of select courses. We have already begun to integrate our AWACS team-organization studies into the curriculum of a Fall ‘99 Leadership course. This integration will provide research and educational benefits by providing broader access to quality teams of cadets, and exposing those cadets to the inner workings of behavioral research through participation as subjects, data analysis, and application of results.

One of the goals of training at USAFA, in general, and the Leadership Reaction Course (LRC), in particular, is having cadets learn how to solve problems effectively as a team. One relatively new idea in the realm of social psychology is that of “teamthink,” in which members of a team focus on the individual and/or strengths of each team member and uses the diversity of the group to help solve problems. In a research project being conducted by members of the Department of Leadership and Behavioral Sciences, the effects of a brief intervention meant to train basic cadets in a teamthink approach to solving problems as presented by the LRC are being examined. The subjects will be approximately 1000 basic cadets participating in Basic Cadet Training. There are three conditions - the experimental condition in which a 5-minute training session on teamthink is presented, a control condition in which a 5-minute training session on core values is presented, and a no-treatment control condition in which there is no intervention whatsoever. The main dependent variable is level of success on a difficult group problem solving task that is part of the LRC and that has only an approximately 50% successful completion rate. The hypothesis is that the teams that receive the teamthink training will successfully complete more components of the solution to a group problem-solving task than groups that receive a similar intervention focusing on core values or no intervention at all. If a brief intervention in team-think is effective in enhancing problem-solving at the LRC, this may have implications for additions to our curriculum in leadership, management, and other courses that require cadets to solve problems in groups.

LCOR Russell Shilling was appointed to the Steering Committee for the Crew System Ergonomics Information Analysis Center (CSEIAC). CSEIAC provides a variety of products and services to government, industry, and academia to promote the use of ergonomics in the design of human-operated equipment. CSEIAC is one of more than 20 Information Analysis Centers that provide technical information services in a variety of subject areas.

Department of Engineering Mechanics

Bonded Repair to Stiffened Panels

The focus of this research is how to repair damaged aircraft structure with composite patches. Today, cracks in USAF aircraft are routinely repaired with riveted doublers or, in cases where such a repair is not practical, the damaged part is often replaced (sometimes at great expense). An alternative method of repair, whose use is becoming more widespread in recent years, is to bond a composite patch over the damage site. This technique is often referred to as "crack patching." Some of the advantages of crack patching over riveted repairs are lighter weight, no drilling new holes for rivets (more damage), and a lower repair profile.

When the Air Force discovered that many of its C-141B Stairlifters had wing cracks just after DESERT STORM, 45 of the aircraft were grounded, and the remaining 198 were put on severe flight restrictions (see http://www.af.mil/news/Jan1995/N19950130_070.html). These wing cracks had to be repaired or the affected wing panels replaced. Riveted repairs were not an option due to the complex structural geometry in the vicinity of the cracks and the high loads on the wing panels, so bonded repairs were used. Though some badly damaged wing panels were replaced, the majority of the repairs were bonded composite patches that were applied both inside the wings and outside. Warner-Robins Air Logistic Center (GA) performed the majority of the repair work. (WR-ALC has a mobile repair capability that travels the world making advanced bonded repairs to USAF aircraft. In addition to the C-141B, bonded repairs have been performed on C-130, B-1B, and F-16 aircraft.)

Follow-on research to this repair effort is ongoing at the USAFA Center for Aircraft Structural Life Extension (CASELE). This research, headed up by Mr. Cornelis Guilt and Mr. Stephan Verhoven, has afforded cadets a chance to get involved in Air Force research of the highest relevance. Cadets have been involved in measuring the strains in stiffened panels that simulate the C-141B wing skin. Their strain surveys have led to a more accurate assessment of the fidelity of these specimens. Other ongoing work at the CASELE includes studying the growth of cracks in the panels when subjected to fatigue loading. Both patched and un-patched panels are included in these studies.

Department of English

Major Thomas W. Krise, Associate Professor and Executive Officer of the Air Force Humanities Institute, has assembled, edited, and written an introduction to an anthology of Caribbean literature, forthcoming shortly from the University of Chicago Press.

Although the colonies in the West Indies were as important to the expanding British empire as those in North America, writings from the British West Indies have been conspicuously absent from anthologies of seventeenth- and eighteenth-century British literature. In this first literary anthology dedicated to the region,
USAFA Discovery #1999-02 (Apr-Jun 99)

Major Krise’s volume include several of the earliest protests against slavery; a superb ode by the Cambridge-educated Afro-Jamaican poet Francis Williams; James Grainger’s extended georgic poem, The Sugar Cane; Frances Seymour’s poignant tale of the Englishman Inkle who sells his Indian savior-lover Yarico into slavery; and several descriptions of the West Indies during the early years of settlement.

Department of Foreign Languages

Air Force Language Link: On-Line Russian Language Maintenance and Development establishes a prototype for Air Force Language Link (AFL), an online Web archive to provide Air Force personnel worldwide with information and authentic materials for maintaining and improving foreign language skills. The technologies employed should apply to other disciplines to foster lifelong learning in virtually all subject matter areas.

Major Stanley Supinski is conducting research on the use of three common educational and communication technologies -- the Internet, compact disk, and email --to study the feasibility of delivering Russian Language maintenance and development in a distance learning mode. Thirty subjects across the Air Force (From Misawa AB, Japan to Langley AFB, Virginia), and several who are deployed or TDY (Bosnia, Vicenza, and others), are participating in the 24-week course. The students will work in cooperative teams of five, using interactive courseware obtained primarily from a CD. They will also interact with each other and a native-Russian course moderator located in Colorado Springs, as well as receive additional, dynamic lessons from a course bulletin board. This truly virtual classroom and course should make optimal use of these technologies while reducing the need to send personnel for expensive in-residence courses. The course should also support the Air Force strategy of “Global Engagement” by increasing Foreign Area Officer and other linguists’ Defense Language Proficiency Test scores. The study and course will be completed in July.

Human-Environmental Research Center (HERC)

During the past year, the HERC:
- Established the AFRL Operating Location in Biology when Dr. Ann Cox arrived in March. We also undertook the hiring of a contract research assistant. Mike Kirk joined us in June.
- Met with scientists at the Soldier Service Center (SSC) and at the Army Research Institute of Environmental Medicine (USARIEM) at Natick MA to coordinate joint research efforts. We drafted an MOA for USAFA-USARIEM research collaboration and initiated in July the first USARIEM collaborative research protocol, involving the USARIEM lab on Pike’s Peak in a study of the effects of acclimatization to moderate altitude on performance at high altitude.
- Co-sponsored with IIT A and DFE the in-house Peaks Project Educational Innovations and Research Symposium (PPERS) in January. Edited and published the Proceedings as a USAFA technical report.
- Hosted visits and presentations by Dr. John Stern, Washington University, St Louis; Prof. Wolf Boucein, U. Wuppertal, Germany; Dr. Alan Gevins, EEG Systems Lab, San Francisco; Maj Neil Baumgartner, Human Performance, Force Enhancement and Fitness Division, Department of Aerospace Physiology and Human Performance, USAF School of Aerospace Medicine; Dr. Stan Barnett, CSIRO, New South Wales, Australia; Dr. Jefferson Koonce, Center for Applied Human Factors in Aviation, University of Central Florida; and Dr. Bjorn Cedervall, Karolinska Institute, Stockholm.
- Supported faculty TDYs to the DOD Human Factors Engineering Technical Advisory Group (HFE TAG) meetings, the Aerospace Medical Association meeting, the Computer-Human Interaction meeting, the Rocky Mountain Bioengineering Symposium, and the Aviation Psychology meeting.
- Reviewed a draft of the AF Inspection Agency’s Eagle Look report on Human Systems Integration in Air Force acquisition.
- Acquired at no cost the Navy’s Automated Portable Test System (APTS) for computerized cognitive testing, and the Basic Flight Instruction Tutoring System (BFITS). Both programs are in use in fledgling research efforts.
- Drafted and revised the questionnaire for the IIT A faculty notebook computer study. Analyzed and reported the demographic data. Completed 20 workstation ergonomics consults for notebook and desktop computer users.
- Created and hosted Airmanship Research Seminars for USAFA faculty and staff.

Dr. Cox conducted a successful pilot study with an international team at Colorado State University. Cell synchronies (by centrifugal elution) and comet assays were performed in the laboratories of Drs. John T. Lett and Susan M. LaRue at Colorado State University. Dr. Stanley B. Barnett (Commonwealth Scientific and Industrial Organisation, Australia) was supported in this endeavor by the Asian Office of Aerospace Research and Development or AOARD (AFOSR) in Tokyo, and Dr Cox was supported by AFRL/HEDB. Besides further characterizing the very sensitive L5176Y S/S cell line’s (and its transfected offspring’s) responses to toxic agents, it is hoped that we will be able to measure DNA damage and repair in neural cells using the comet assay.

34th Education Group

C1C Jeffrey J. Schrum presented his paper, “The German Speaking New Right: Culture Clashes in a European Context,” at the European Community Studies Association (ECSA) Conference from 2-5 June 1999, held in Pittsburgh, PA. ECSA is one of the foremost scholarly organizations in the United States that follows European issues. Cadet Schrum was chosen to attend the conference as a result of a contest sponsored by the Western European Study Group of the Academy (WEASG) and organized by Lt Col Peter J. Heinz (DF), President of the WEASG, and Dr. Charles Krupnick of the 34th Education Group. The trip was funded by a grant from the McDermott Foundation.


Investments and Programs,” Journal of Applied Management and Entrepreneurship, Jan 99.

Publications and Presentations

34th Education Group

USAFA Discovery #1999-02 (Apr-Jun 99)


Presentations:


Department of Aeronautics

Publications:


Presentations:


Department of Biology

Publications:


Presentations:

DEFUSCO, R. "Birds and Flight Safety in the Middle East." Proceedings of International Meeting, Tel Aviv, Israel, Apr 99.


OBRINGER, J. "The Human Genome Project." AAAS SWARM Meeting, Santa Fe, NM, Apr 99.


SULLIVAN, R. "Instrument Panel Scanning Analysis in the F-117A Stealth." Tri-Beta Biological Meeting, Grand Junction, CO, April 1999. (Café)


Department of Computer Science

Publications:


Presentations:


Education Directorate

Publications:


REVAK, Marie A., "USAF Academy Assessment Catalog: Hot Off the Press." USAFA Educator 7.3

REVAK, Marie A., "Ten Ways to Get Feedback on Your Teaching." USAFA Educator 7.2.


REVAK, Marie A., "Got a Minute? Do Assessment." USAFA Educator 7.1.

REVAK, Marie A., "Focus on Assessment ... Writing a Better Test: Part I." Colorado
USAFA Discovery #1999-02 (Apr-Jun 99)

Mathematics Teacher 31.4. Reprinted in the Wisconsin Teacher of Mathematics 49.3.

Presentations:

HALLORAN, Margaret E. "Analysis of Foraging and Caching Behavior by Abert Squirrels: When the Grasshopper's Strategy is Better Than the Ants". Pike's Peak Chapter of Sigma Xi, Colorado Springs, CO, Feb 99.


MILLIS, Barbara and three USAFA Cadets, "Student Leadership Teams," Educating Our Nation's Leaders, West Point, April 1999.

MILLIS, Barbara. "Creating a Personal Statement [for Medical School Applications]," Workshops for FDB Cadets, March 99.


Department of Engineering Mechanics

Publications:


Department of Foreign Languages

Publications:


HUGHES, H. "Build the Culture Bridge." People's Daily National Newspaper Apr 12, 98.

Presentations:
USAFA Discovery #1999-02 (Apr-Jun 99)


SUPINSKI, S. B. "Cooperative Learning and Technology." USAFA CEE Presentation Series, April 1999.


HAMMOUD, S. D. "Language Policy and Identity Issues in Morocco." American Council for the Study of Islamic Societies, Villanova University, Villanova, PA, April 1999.


Department of Management


Presentations:


Department of Mathematical Sciences

Publications:


HADFIELD, S. "USAFA Research Tracking Ver 1.07." April 1999.


Presentations:


USAFA Discovery #1999-02 (Apr-Jun 99)

Site Selection." 36th Space Congress Proceedings, Cape Canaveral, FL USA, Apr99.

Department of Physics

Publications:


Presentations:


PATTERSON, E.T.  "Using the Web for Teaching and Learning Physics: Win, Lose, or Draw?", Colloquium for University of Nebraska Department of Physics and Astronomy and astrophysics "Just-in-Time Teaching" Workshop, Lincoln, NE, April 1999.

Department of Political Science

Publications:


Presentations:

CARRESE, P. O.  Co-directed a two-day academic conference on "Statesmanship, Character, and the Defense of Liberty" in Aspen, June 1999, for The Liberty Fund.

JONES, V. D.  "Regional Governance: New Approaches for Governing Regions Within the US." Maxwell School of Citizenship and Public Affairs, Syracuse University, NY, Jan 99.


PILCH, F. T.  "Teaching Students Interview Techniques." Midwest Political Science Association Meeting, April 1999.

VALLANCE, B. J.  "Are Civic Associations Making a Difference in Russia?" Rocky Mountain Association of Slavic Studies and the Western Social Sciences Association Annual Conference, April 1999.
**USAFA Research Points Of Contact**

To learn more about research at the United States Air Force Academy, we encourage you to visit our Web site at www.usafa.af.mil/dfe. If you want to focus on a particular department or effort you might want to contact the associated Department Research Director. Each phone extension is preceded by (719)-333 commercial or 333 DSN. Each e-mail is followed by @usafa.af.mil

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