

APPENDIX A

**GENESIS II: ADVANCED LUNAR OUTPOST
SPACE ARCHITECTURE II DESIGN STUDIO**

Architecture 690 - Section 801

Department of Architecture
in cooperation with
College of Engineering and Applied Science
University of Wisconsin-Milwaukee

NASA/USRA Advanced Design Program in Space Architecture
in conjunction with
NASA/Johnson Space Center

Capstone Design Studio
Spring 1991

Instructor Gary T. Moore

NASA/USRA Teaching Assistants Joseph P. Fieber
Janis Huebner-Mothes
Kerry L. Paruleski

Visiting Critics B.J. Bluth, NASA Headquarters

John Cain, Kahler Slater Architects, Milwaukee

John Connolly, NASA Johnson Space Center, Houston

Thomas M. Crabb, Orbital Technologies Corporation, Madison

Wallace Fowler, University of Texas Department of Mechanical Engineering

Robert Greenstreet, UW-Milwaukee School of Architecture and Urban Planning

Nancy Jaeger, UW-Milwaukee Departments of Architecture and Urban Planning

Mike Roberts, NASA Johnson Space Center, Houston

Douglas C. Ryhn, UW-Milwaukee Department of Architecture

Anthony J. Schnarsky, UW-Milwaukee Department of Architecture

Mark Sothman, UW-Milwaukee Department of Human Kinetics

Robert Webber, Marquette University Department of Mechanical Engineering

Course Architecture 690 (U/G), La 801 (3 or 6 credits)

Location Engelmann 223; reviews and seminars in Engelmann 128

Time Tuesdays and Thursdays 1:30-5:20 for 3 credit students; 6 credit students will also meet Fridays 1:30-5:20; every one is expected to be present during these times. There will be other required, scheduled events for special guests, seminars, and reviews. Additional time in studio is expected for individual work.

Office Hours Gary Moore / Eng 172 / T/Th 9:00-12:00
TAs / Eng 223 / during class times

Purpose Students at UW-Milwaukee may become involved in an interdisciplinary design program to work with and present their ideas to a real client—NASA, and to learn about areas of design related to health and safety, psychological and social issues, habitability, underground architecture, interior architecture, construction technology, hi-tech materi-

als, mechanical systems, structural analyses and structural systems, energy systems, site planning, and long-range master planning.

Design Program The Department of Architecture, through its 3-year Advanced Design Program grant from NASA/USRA, is conducting a series of seminars (fall semester) and design studios (spring semester) on space architecture. The Department is one of only three architecture schools in the 41-university NASA/USRA Advanced Design Program. We are working in cooperation with the Departments of Mechanical and Civil Engineering who send us students and faculty advisors every year. The program stresses the systems approach to design in which we work together like an interdisciplinary A/E professional firm on a major real world project for NASA.

History Following criteria provided by consultants from NASA's Johnson Space Center (NASA/JSC) and one of its prime contractors, McDonnell Douglas in Houston, last spring's studio designed *Genesis I*, an early stage lunar outpost for the year 2005. The results were reported at the NASA/USRA meeting, in the USRA conference proceedings, and at one other national and one international conference.

Description In the spring of 1991 we will design an advanced lunar outpost, *Genesis II*, for the year 2005. *Genesis II* will provide housing, research space, mission control space, and all amenities for 11 astronauts to live on the moon for durations up to 20 months. It will serve as an evolutionary, long-term testbed for all materials, processes, and development strategies to be employed in a mature lunar colony for the next 20 years, and as a research and construction technology testbed for all processes to be employed in the exploration and settlement of Mars.

The lunar outpost will include base master planning and schematic design for a mission focused on five experimental systems:

- a. lunar mining and production analysis for lunar oxygen and helium,
- b. lunar construction technology testbed,
- c. a closed system ecological life support facility (biotron),
- d. a lunar far-side observatory,

- e. a human factors and environment-behavior research monitoring facility.

Design development will focus on the central telerobotic command center running these mission operations, on one of the research or manufacturing facilities, and on the crew support habitat.

Design issues to be considered will include base master planning and phasing, human factors, psychological and social reactions to long-duration space missions, high-tech materials and construction technology, lighting, mechanical, and HVAC/ECLSS systems, energy systems, and overall design aesthetics.

The design will be based on a programming document produced in Arch 390/790 Space Architecture Seminar offered in the fall of 1989, the final design document produced in Arch 690 Space Architecture Studio offered in the spring of 1990, and several independent study projects completed during the fall of 1990.

Structure and Schedule

Studio will be structured in six segments:

1. Readings, slide talks, and individual sketch design explorations. 2 weeks. Preliminary Design Review (PDR-I) by NASA officials, university faculty, invited consultants.
2. Research and design studies of different issues, e.g., lunar site design, 1/6th gravity, workstations, natural light, underground architecture, inflatable dome construction, hi-tech materials like elastomers and thin films. 3-1/2 weeks. PDR-II.
3. Preliminary design to develop and explore different parti. 1-1/2 weeks. PDR-III.
4. Design development of different parts of overall lunar base. 2 weeks. Intermediate Design Review (IDR) with national guests.
5. Design integration to present final integrated design. 3-1/2 weeks. Not-quite-final Design Review (NQFDR).
6. Presentation. 1-1/2 weeks. Final Design Review/Final Jury (FDR).

Key A/E Design Issues Based on our self-critique of last year's work, and very helpful suggestions from James Burke, NASA/Jet Propulsion Laboratory, and Stephen Paddack, NASA/Goddard Space Flight Center, areas of detailed investigation will include, but not be limited to, the following:

- a. Character of the lunar environment with design studies on implications of the lunar topography, atmosphere, radiation levels, solar flares, power sources, temperature extremes, and in-situ materials.
- b. Long-term effects of reduced gravity and design studies on different approaches to creatively designing for 1/6th gravity.
- c. Extraction of design-relevant implications from previous space experience, analogous situations, and simulations, e.g., Mir and Skylab, Antarctica and Navy submarines, and Tektite.
- d. Space allocation studies including human factors analysis of the minimum space required for different lunar habitation and research functions.
- e. Design trade studies of different areas of a lunar habitat, e.g., health maintenance facility, exercise facility, crew quarters, air locks, and workstations; development studies of these areas including study perspectives and models.
- f. Design studies of different ways of getting natural light into a regolith-covered lunar habitat without admitting gamma ray particles, including partially covered cupolas, flexible light pipes, periscopes, etc.
- g. Habitability design study of the short- and long-term effects of underground, windowless architecture.
- h. Design replacement studies of how to replace/renovate parts of a habitat without disturbing ongoing functions.
- i. Design studies of construction technologies including prefabricated modules, rigid structures, inflatables, and in-situ resource utilization.

- j. Structural design studies and calculations for all structural members including inflatable domes.
- k. Design studies of the implications of new, hi-tech materials especially elastomers and thin films, e.g., Kevlars, Mylars, Spectra, Nomex, aluminums, titaniums, rigidizing foams, and in-situ resource utilization of lunar regolith.
- l. Mechanical design study of radiators to remove body and machinery heat from under-regolith.
- m. Regolith depth studies of the minimum depth of regolith to protect lunar habitats from radiation and micrometeoroids, and design studies of regolith containment systems, second-generation regolith bagging machines, and processes (including sequences) of habitat construction.
- n. Mass calculations, studies of ways to reduce mass, rough-order-of-magnitude (ROM) cost estimates, and analysis of total number of flights based on minimum mass calculations.

Eligibility/Prerequisites Students from architecture (undergraduate and graduate) and from engineering (especially mechanical, structural, and industrial/systems) are welcome to join this studio. It is not necessary to have taken the earlier space architecture seminars or studio. The most important prerequisite is a love for space and a commitment to aerospace studies. Specific prerequisites include a minimum of Arch 100, 101, 200, 202, and senior standing, or signed consent of the instructor. It is recommended to have also taken Arch 300, 301, 302, 303, and 400, 401, 402, or be a senior in Engineering. The course counts as studio credit in both the undergraduate and master's programs in the Department of Architecture, and as credit for the engineering capstone design requirement in the Departments of Mechanical and Civil Engineering (contact Prof. Ryoichi Amano in Mechanical Engineering and Profs. Al Ghorbanpoor, Fattah Shaikh, or Edward Beimborn in Civil Engineering for details on how to enroll). Students should enroll for Arch 166-690, Section 801, for 3 or 6 credits. If it is absolutely necessary to enroll for engineering credit, then it is required to also enroll formally for "Audit" status in 166-690.

Instructor The instructor, Gary T. Moore, Ph.D., is Professor of Architecture and Project Director of the NASA/USRA Advanced Design Program in Space Architecture. (I am previously committed to several conferences this semester, and will be away as noted on the syllabus below). The TAs, Joe P. Fieber, Kerry L. Paruleski, and Janis Huebner-Moths, are advanced undergraduate or graduate students in the Department of Architecture and all have worked for the aerospace industry (Fieber/Paruleski at NASA/Johnson Space Center and Moths at Orbital Technologies in Madison). We will be joined by special guests and visiting critics selected from the above list from the Advanced Programs Office at NASA Johnson Space Center (NASA/JSC), NASA/USRA, McDonnell Douglas Astronautics Corporation in Houston, Astronautics Corporation of America, Orbital Technologies Corporation, and private A/E firms. Other faculty from the UW-Milwaukee Departments of Architecture, Mechanical Engineering, and Civil Engineering will also serve as guest critics. Reviews at key milestones (preliminary, intermediate, and final design reviews) will be conducted by the studio faculty and these visiting critics.

Studio Everyone is expected to work in studio. Individual studio workstations will be provided. Computer graphics/CAD machines will be available in Engelmann 223 for exclusive use of the students enrolled in this studio.

Readings There are three required books for this studio:

Cordes, E.G., Hansmann, T., Fieber, J.P., Paruleski, K.L., Moths, J.H., & Moore, G.T. (Eds.) (1991). *Space architecture design seminar/workshop: Space architecture reader* (Rev. ed., 2 vols.). Milwaukee: University of Wisconsin-Milwaukee, NASA/USRA Advanced Design Program in Space Architecture. Pp. ca. 300/volume. Ca. \$10.00/volume — available from Clark's Graphics on Oakland Avenue. ("Reader" in the below assignments.)

Baschiera, D.J., Fieber, J.P., Moths, J.H., Paruleski, K.L., & others (1989). *Genesis Lunar Outpost: Program/requirements document for an early stage lunar outpost* (ed. by E.G. Cordes). Milwaukee: University of Wisconsin-Milwaukee, Center for Architecture and Urban Planning Research, Report R89-1. Pp. 91; figures, charts, tables. \$10.00 — available from CAUPR, Engelmann 158. ("Program" in the below assignments.)

Hansmann, T., & Moore, G.T. (Eds.) (1990). *Genesis Lunar Outpost: Criteria and design*. Milwaukee: University of Wisconsin-Milwaukee, Center for Architecture and Urban Planning Research, Report R90-1. Pp. xiv + 107; plans, illustrations, tables, references. \$10.00 — available from CAUPR, Engelmann 158. ("Final Design Report" in the below assignments.)

Please purchase these on the first day of class. Students who have not taken previous work in space architecture should immediately read as much as possible from the Space Architecture Reader. All students should read or review *Genesis Lunar Outpost: Program/Requirements Document for an Early Stage Lunar Outpost* and especially *Genesis Lunar Outpost: Criteria and Design*, within the first two weeks of the semester. Other hard-copy documents, papers, microfiche, and slides are available in the CAUPR Research Room, Engelmann 258, and in the studio. Other readings from these sources will be recommended as needed. All readings are to be done prior to the seminar or slide lecture at which they will be discussed.

Assignments The principle assignments will one research and design project and three design projects including final presentation. Other assignments will include the required readings for each seminar or lecture.

Final Products The final products will be a set of design drawings, presentation boards suitable for exhibition, a model, a slide presentation, and a final written/graphic report. They will be presented to NASA/USRA and, like last year, at several regional, national, and perhaps international meetings. All costs associated with final presentations are underwritten by the NASA/USRA grant.

Conferences The final drawings and model will be presented by the students at the annual NASA/USRA Conference being held this year at NASA/Kennedy Space Center, June 17-21, 1991. Proposals for presentations at other national and international aerospace conferences are under review. We have already received an acceptance to present our work at the 10th annual International Space Development Conference of the National Space Society, San Antonio, Texas, May 22-27. In addition, there will be opportunities for the most advanced students to make presentations of our work at various other conferences and meetings locally and regionally.

Evaluation Evaluation will be based on how much you personally have developed over the semester, and will be based on evidenced knowledge of the material from the readings and lecture/seminars including seminar participation (20%), research and design study (PDR-II; 20%), parti development (PDR-III; 10%), design development (IDR; 15%), design integration (NQFDR; 15%), and contribution to the final presentation and product (FDR; 20%). While the TAs will advise on these matters, the final grades will be assigned by the instructor.

Funding The Advanced Design Program in Space Architecture is being underwritten by a three-year grant from NASA/USRA which supports the TAs and will pay for out-of-pocket expenses on the project and most of the travel expenses to the conferences for selected students. The best student will be invited to continue next year as the NASA/USRA sponsored TA for this studio following a paid training period this summer at the NASA Johnson Space Center.

Special Conditions For those of you familiar with studios, this will be a very different studio. For those of you from Engineering or earlier in your architecture career not familiar with studios, this will be a very different experience. I'll explain the differences at the first class, and answer your questions as best I can. But in a nutshell, this is a learning studio, a nationally funded project, and a group of aerospace nuts working and having fun together. My commitment is two-fold: to your education, and to the project and our client—NASA. Your commitment needs also to be two-fold: to your education, and to the project, and it needs to be a very real commitment. The project will be demanding, perhaps more so than any course or studio you have ever taken. But it will also be rewarding, and it should be fun. Already we have planned for you involvement in a regional conference that will include nationally recognized aerospace speakers (you'll have a chance to meet them over dinner, and to have them review your work at a late-night soiree). The best students will represent the class/project at the NASA/USRA conference at the Kennedy Space Center in June. Last year we were interviewed by radio, newspapers, and TV, and made presentations at a variety of local affairs—I hope you'll all have a chance to be involved in this way again this year. We prepared an exhibit of our work which was displayed twice in Wisconsin and once in Illinois—we still have the display and can prepare a second edition if called upon. The students received a special design commendation award from the Environmental Design Research Association (EDRA) for this work. We may do pot-lucks or other informal events, dinners at Kalt's, etc., when we have special guests in town. Other ideas are up to you.

GENESIS: LUNAR OUTPOST II

SPACE ARCHITECTURE II DESIGN STUDIO

Architecture 690 - Section 801

SYLLABUS

Spring 1991

Week / Date	Topic / Assignments / Readings / Reviews / Visiting Critics
Part I	The Space Environment: Readings, Slide Lectures, and Individual Sketch Design Explorations
1 / Jan 15 (T)	<p>Opening discussion: Purpose and objectives of the NASA/USRA Advanced Design Program in Space Architecture, Gary Moore, TAs, and class. Buy text books, set up studio, and begin reading.</p> <p>Lecture: History of the Space Program, Jan Moths.</p> <p>Lecture: The Environment of the Moon, Jan Moths.</p>
Jan 17 (R)	<p>Required reading: Reader —</p> <p>Section A (all):</p> <ul style="list-style-type: none"> Sutphin (1988) Higgins (1989) Cordes (1988) National Space Council (nd) Cordes & Patton (1988) <p>Section B (all):</p> <ul style="list-style-type: none"> Moore (1989) Weiss & Freiherr (1989) <p>Section D (all):</p> <ul style="list-style-type: none"> Crabb (1989) Moths (1990) Robinson (1989)

Required reading: Program —
Scenario, pp. 1-4. Skim rest of document so you'll know what's where for future reference.

Required reading: Final Design Report —
Chapter 5, Introduction, pp. 1-10.
Skim Chapters 6-7, reading as much as you can.
Chapter 7.2, Integrative Design, pp. 66-89.

All required reading is to be completed prior to class so that you can enter actively into the discussion, ask pertinent questions of the lecturers, etc.

1:30 Lecture: Design of an Inflatable Habitat for NASA's Proposed Lunar Base, Joe Fieber and Kerry Paruleski.

2:45 Lecture: Genesis Lunar Outpost: Criteria and Design. Description of last year's work, Gary Moore.

3:30-5:20 Self-critique of last year's work: Genesis I Lunar Outpost, based on your reading from the Reader, Program, and Final Design Report, and the week's lecture/seminars.

One-week Design Charette: Individual sketch designs for an overall lunar base. Problem statement handed out at end of class.

2 / Jan 22 (T)

Required reading: Reader —
Section F:
Anonymous (nd)
Connors, Harrison & Akins (1985)
Moore (1988)
Section G:
Clearwater (1985)
Cranz, Eichold, Hottes, Jones & Weinstein (1985)
Lebedev (1989)
Connors et al. (1985)
Moore (1990)

1:30 Lecture: Human Factors—Anthropometric, Physiological, Medical, Health, and Safety Issues, Kerry Paruleski.

Desk crits of individual sketch designs by instructor and TAs.

4:30 Lecture: Environment-Behavior Factors—Psychological and Social Issues, Kerry Paruleski.

Jan 24 (R)

Preliminary Design Review: Individual Sketch Designs (PDR-I) — due
Thursday, January 24, 1:30-4:30 p.m., Studio

Organization of issues and questions for further research and design studies.
(Faculty and TA meeting every Thursday, 4:30-5:20, Room 172.)

Part II

Research and Design Studies

3 / Jan 29 (T)

Required readings: Reader —
Section E: Space Analogies, Simulations, and Previous Space Exploration
NASA (1989)
David (1988)

Required reading: K. Paruleski (1990), A comparative analysis of analogous situations, previous space exploration, simulated situations, and future conditions. Independent study report, Advanced Design Program in Space Architecture, Department of Architecture, University of Wisconsin-Milwaukee. Section on Previous Actual Space Exploration.

1:30 Lecture: Lessons from Previous Actual Space Exploration, Kerry Paruleski.

Selection/assignment in class of different issues and questions for research and design studies, e.g., lunar

Jan 31 (R)	<p>site design, 1/6th gravity, workstations, natural light, underground architecture, inflatable dome construction technology, hi-tech materials like elastomers and thin films, and others from PDR-I. Work individually or in pairs.</p> <p>Required reading: Reader — Section E: Klassi (1988) Johnson & Kingsley (1988) Stuster (1986)</p>	6 / Feb 19 (T)	<p>Preliminary Design Review: Presentation of Research and Design Studies — oral, graphic, and written/graphic report (PDR-II) — due Tuesday, February 19, 1:30-4:30 p.m., Studio.</p> <p>Two-day Design Assignment: Individual sketch designs to identify a range of overall base design parti — minimum one parti per person; assignment at end of class.</p>
<p>1:30 Lecture: Lessons from Analogous and Simulated Situations, Kerry Paruleski.</p>		<hr/> Part III Preliminary Design <hr/>	
4 / Feb 5 (T)	<p>Research and design studies. Work in studio and library. Desk crits by instructor and TAs. (If you're working in the library, please check in at the studio with the TAs or instructor before heading over.)</p> <p>Required reading: Reader — Section E: Anderson (1989) Space Biospheres Ventures (1990)</p>	Feb 21 (R)	<p>Review of individual sketch design parti — due Thursday, February 21, 1:30 p.m., Studio.</p> <p>One-week Design Charette: Preliminary sketch designs to explore and develop the most promising different parti. Work in teams (4-5 teams). Assigned at end of class.</p>
Feb 7-8	<p>1:30 Lecture: Lessons from "Future Conditions," Kerry Paruleski.</p> <p>Desk crits by instructor and TAs.</p> <p>Continuation of research and design studies. Desk crits by instructor and TAs.</p>	7 / Feb 26 (T)	<p>Desk crits on preliminary sketch designs.</p> <p>(GTM @ University of Puerto Rico as visiting design critic on their Advanced Design Program in Space Architecture, February 22-27. TAs in charge.)</p>
Feb 7-8	<p>Desk crits by instructor and TAs.</p>	Feb 28 (R)	<p>Preliminary Design Review: Design Parti (PDR-III) Thursday, February 28, 1:30-4:30 p.m., Engelmann 128.</p>
5 / Feb 12-15	<p>Completion of research and design studies. Desk crits by instructor and TAs.</p> <p>(GTM visiting lecturer @ Georgia Institute of Technology, and juror @ ACSA Student Research Competition, Kansas City, February 13-17.)</p> <p>Possible party, Friday, February 15.</p>	<hr/> Midterm <hr/>	

Part IV

Design Development

8 / Mar 5-8

Design development: Groups work on design development of different parts of the overall lunar base. One group per part (3-4 groups); TAs as team leaders for groups especially for overall master-plan/site design team.

Readings from rest of Reader, Sections H, I, and J.

Lectures on lunar construction technology, etc.

9 / Mar 12-17

Completion of design development.

Wisconsin Aeronautics and Aerospace Conference Saturday-Sunday, March 16-17, 9:00 a.m.-5:00 p.m. (recommended).

Dinner at Embassy Suites, Saturday, March 16, 7:30 p.m. (optional).

Intermediate Design Review (IDR-Part 1). Saturday, March 16, 9:00 p.m., 2250 La Fontaine Ct., Brookfield

Visiting Critics:

John Connolly, NASA/JSC

Mike Roberts, NASA/JSC

Wallace Fowler, University of Texas, Austin

Party with national aerospace guests following.

(GTM @ Space Grant Conference, Huntsville, Alabama, March 9-17.)

10 / Mar 19 (T)

IDR-Part 2: Preparation for design integration, review of comments from IDR, selection of best design concepts, and plans for integration Tuesday, March 19, 1:30-4:30 p.m., Studio.

Spring Recess

Part V

Design Integration

Mar 21 (R) Full team design integration to prepare the final integrated design.

11 / Apr 2-5 Design integration.

12 / Apr 9 (T) Complete design integration.

Apr 12 (R) Not-Quite-Final Design Review (NQFDR); Thursday, April 18, 1:30-4:30 p.m., Engelmann 128.

Part VI

Presentation

13 / Apr 16-18 Final presentation

14 / Apr 23-26 Final presentation

15 / Apr 30 (T) Final Design Review / Final Jury (FDR); Tuesday, April 30, 1:30-5:20 p.m., Engelmann 150. Party or at least drinks and dinner @ Kalt's following.

May 22-27 National Space Society 10th annual International Space Development Conference, San Antonio, Texas (optional — GTM and TAs have a paper accepted).

May 31 USRA Final Report completed by TAs — submitted to GTM.

June 17-21 USRA 7th annual Summer Conference, Kennedy Space Center, Florida (required for faculty, TAs, and next year's TA; optional for others — class will present paper and small exhibit).