

**Final Report**  
**NASA/USRA**  
**University Advanced Design Program**  
**at the**  
**University of Illinois**  
**for the**  
**1988-1989 Academic Year**  
*NASW-4435*

**by**  
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Abstract

This report reviews the participation of the University of Illinois at Urbana-Champaign in the NASA/USRA University Advanced Design Program for the 1988-1989 academic year. The University's design project was the Logistics Resupply and Emergency Crew Return System for Space Station Freedom. Sixty-one students divided into eight groups, participated in the Spring 1989 semester. A presentation prepared by three students and a graduate teaching assistant for the program's summer conference summarized the project results.

Teamed with the NASA Marshall Space Flight Center (MSFC), the University received support in the form of remote telecon lectures, reference material, and previously acquired applications software. In addition, a graduate teaching assistant was awarded a Summer 1989 Internship at MSFC.

## Introduction

This is the fourth year that the University of Illinois has participated in the NASA/USRA University Advanced Design Program. Past projects have included the Lunar Oxygen Transportation System (1985-86), the Two-bodied Comet Explorer (1986-87), and the Manned Marsplane and Delivery System (1987-88). In keeping with the past philosophy of studying a new project each year, the Logistics Resupply and Emergency Crew Return System for Space Station Freedom was selected for this year's project.

The project concept was approved by Frank Swalley, the University's contact at MSFC early in the Fall 1988 semester. Details of the interaction between MSFC personnel and the University were worked out generally in the Fall of 1988 and specifically during the Spring 1989 semester. A detailed schedule of events is presented in Appendix A.

## Course Organization

The University's AAE 241 aerospace vehicle design course is comprised of two sections, one each for spacecraft and aircraft design. Based on individual interests and introductory information provided at the first class meeting, AAE 241 students choose one of the sections and are usually divided into two independent groups. Of the 118 students enrolled in AAE 241, 57 selected the aircraft section and 61 selected the spacecraft section. The class roster is given in Appendix B.

The Request for Proposal (RFP) given to the spacecraft section is presented in Appendix C. This document lists the mission design objectives and constraints and contain several requirement conflicts and ambiguities which had to be resolved by the students.

At the first meeting of the class, students were asked to fill out a questionnaire in order to identify courses they had taken and their preference of technical areas (at the spacecraft subsystem level). Based on these results, the students were divided into six competing design groups (additionally, one group was formed to work on this year's AIAA/Allied Solar Sail Design Competition and one group was formed to support a department proposal response effort). Each group was responsible for a complete vehicle design.

The course was under the direction of Professor John Prussing. The spacecraft section teaching assistants were Michael Lembeck and Andrew Koepke. Dan Bain, a AAE 241 veteran acted as spacecraft section

assistant. Each project group, in turn, selected a leader responsible for group coordination and preparation of weekly status reports to the section staff.

Fifteen homework assignments were assigned in the spacecraft section, exposing all the students to subsystem design analysis. Several of these assignments required the students to make use of software written by the teaching assistants and others and made available on twenty IBM ATs in an open computer laboratory. This software included:

MIND - Mechanically Intelligent Designer, an expert system shell for which the students generated design rules to perform conceptual spacecraft design. This program is also serving as an interim planning tool for strategic planning at OSSA under Joe Alexander.

ITAS - Interactive Thermal Analysis Software

INERT - program for determining spacecraft composite inertia and mass properties.

SCSIM - scan platform dynamics and control simulation program.

Each student gave a five-minute, midterm oral viewgraph presentation representing an RFP response. Emphasis was placed on the identification of requirements and trade studies to be undertaken for the final design. At the end of the semester, a Final Design Report was submitted by each project group and summarized in another oral presentation for both AAE 241 sections (aircraft and spacecraft).

#### NASA/MSFC Remote Lectures

Frank Swalley of MSFC provided reference contacts for University interactions with MSFC. As a result of these contacts, two Marshall engineers participated in remote telecon lectures. Each lecturer provided viewgraphs in advance of his presentation and copies were distributed to the students. A question and answer session followed each lecture, allowing the students to interact with the NASA professionals in a relaxed, albeit distant, manner. Lead MSFC participants included:

Frank Swalley - systems engineering

Dr. Randy Humphreys - life support systems

### Other Guest Lectures

In addition to the MSFC telecons, several industry representatives delivered in-class presentations on various topics. The guest lecturers, their affiliations, and the topics they discussed were:

Mel DeSart - University of Illinois Library System, locating pertinent information from technical sources

Scott Meyer - SAIC, reentry trajectory problem

Dr. Stephen Hoffman - SAIC, CRAF/CASSINI mission

Jim Schlueter - McDonnell Douglas Aircraft, details and thoughts behind a major NASP presentation

### Results

The resulting designs were presented in the groups' Final Design Reports. Copies of these reports are included with this report. A summary report was filed with USRA on June 20, 1989.

### Summer Program

Andrew Koepke was selected again as the MSFC summer intern. Last year, Mr. Koepke found the experience beneficial in preparing to act as teaching assistant in AAE 241.

Students interested in attending the USRA summer conference at MSFC submitted letters of application early in the semester for review. The three students selected were John Beirne, Susan DelMedico, and Carrie Sumner.

As a dress rehearsal for the summer conference, these three students, along with teaching assistant Koepke, made a presentation at a special evening meeting of the University's AIAA student branch on May 10, 1989. The presentation, repeated at MSFC on June 13, 1989, summarized the class organization, design issues investigated, and results obtained by the design groups.

In addition to the three undergraduates and Koepke, sufficient funds were available to allow Professor Ken Sivier, teaching assistant Michael

Lembeck, and graduate assistant Dan Bain to attend the summer conference.

### Evaluation

Before leaving campus, the student participants were asked to fill out a USRA provided card related to the impact of the USRA program on their opinions and future careers. These cards are included with this report. While generally favorable opinions of the course were rendered, the teaching assistants noted an overall lower quality (as compared to recent years) in the design reports submitted by the students. It is believed that the instability of commitment to the space station program combined with a declining aerospace job market resulted in student motivation problems and a general lack of interest in this year's design topic.

On the plus side, last year's project, the Marsplane, is still generating favorable fallout for the program. Sivier and Lembeck made an invited presentation on the Marsplane at the May 1989 Space Development Conference of the National Space Society in Chicago.

One programmatic item of concern that still needs to be addressed is the geographic problem of interacting with MSFC personnel. While the remote telecons provide some access to the center, funds should be made available for MSFC personnel to travel to the University for in-person presentations and longer discussions with the students working on design projects. If such a level of "inter-activity" was possible, it would lead to more technically significant and applicable results being obtained from the program.

Resources provided by the Advanced Engineering Design Program add credibility and substance to the AAE 241 Aerospace Vehicle Design course at the University of Illinois. Contact with aerospace professionals working on real problems gives the students a point of reference, early in their careers. In conclusion, University participation in the Advanced Engineering Design Program has been beneficial for all involved organizations.

**APPENDICES:**

- A: Calendar of Events
- B: Class Roster
- C: S/C RFP

**Appendix A**  
**Calendar of Events**

**AAE 241**

**Spring 1989**

This document outlines the AAE 241 schedule referred to in the Request for Proposal for a Logistics Resupply and Emergency Crew Return System for Space Station Freedom (section VIII). This outline is subject to change based on availability of guest lecturers, and other circumstances beyond the control of the course instructors. Actual homework due dates will be given when the homework is assigned.

**Tues 1-24**

- introduce project
- handout project RFP
- explain grading
- review course schedule
- homework # 1: complete class survey, and technical preference/  
group-mate questionnaire
- # 2: distill requirements from RFP, noting conflicts  
and ambiguities

**Thurs 1-26**

- design theory: what is design, methodology, etc.
- introduce computer utility for design
  - \* MIND, Mechanically INtelligent Designer expert system
- homework # 3: teach MIND to design spacecraft

**Tues 1-31**

- guest lecture: Frank Swalley, MSFC, Systems Engineering (Teleconference)
- more design theory

**Thur 2-2**

- guest lecture: Mel Desart, "Using the University's Information Resources"
- space station threats, hazards demanding CERV



Tues 2-7

- environmental control and life support systems
- homework #4: life support sizing

Thur 2-9

- logistics resupply mission requirements

Tues 2-14

- discuss attitude control subsystem components-function
- automated rendezvous and docking
- homework #5: logistics up/down mass/volume calculations
- homework #6: delta-v and tank sizing for docking maneuvers

Thur 2-16

- discuss communications subsystem
- homework #7: communications trade studies, sizing, component selection

Tues 2-21

- discuss proposal response oral presentation format
- review and questions
- homework #8: prepare oral response to proposal

Thur 2-23

- micrometeorite/radiation protection systems

Tues 2-28

- guest lecture: Dr. Randy Humphreys, MSFC, Life Support Systems (Teleconferenc
- introduce computer utility for inertia configuration analysis
  - \* INERT, generate composite center of mass, moments of inertia
- homework #9: run INERT to determine acceptable inertia configuration and draw spacecraft component layout

Thur 3-2

- orbital mechanics basics
- introduce computer utility for orbital studies
  - \* MULIMP, compute orbit parameters and delta-v
- homework #10: transfer orbit delta-v analysis
- discuss propulsion subsystem

Tues 3-7

- discuss spacecraft dynamics
- introduction to simulation software

Thur 3-9

- discuss power subsystem
- homework #11: power trade studies, sizing, component selection

Tues 3-14

- response to proposal oral presentations

Thur 3-16

- response to proposal oral presentations

Tues 3-21

\* spring break \*

Thur 3-23

\* spring break \*

Tues 3-28

- PDR Evaluations

Thur 3-30

- guest lecture: Scott Meyer, SAIC, reentry dynamics and systems

Tues 4-4

- thermal control
- homework #12: thermal control

Thur 4-6

- control system design theory
- introduce computer utility for dynamics and control simulation
  - \* SCSIM, basic dynamics and control simulator
- homework #13: simple scan actuator gain computation

Tues 4-11

- mission costing
- mission planning, command and telemetry requirements
- homework #14: Final report outline

Thur 4-13

- guest lecturer: Dr. Steve Hoffman, SAIC, CRAF/CASSINI missions

Tues 4-18

- homework #15: in class Tiger Team Response exercise

Thur 4-20

- guest lecture: Jim Schlueter, MCDAC, NASP program review

Tues 4-25

- question and answer time

Thur 4-27

- misc. topics on work in the "real world"
- spacecraft test considerations

**Tues 5-2**

- written final design reports due 2:00 pm
- final presentation slides due 2:00 pm (2 copies)
- group final design report presentations

**Thur 5-4**

- group final design report presentations

**Tues 5-9**

- group final design report presentations

**Wed 5-10 (evening)**

- special NASA/USRA summary report presentation
- AAE 391 AIAA design group presentation/demonstration

## Appendix B

### AAE 241 Class Roster Spring 1989

#### Group 1 AIAA Solar Sail

Enrico	Attanasio
Charles	Carter
John	Collins
Dave	Crean
Tonia	Foster
Jeff	Grusy
Paul	Higgins
Robert	Reiher
Tim	Stuit
Walter	Waltz

#### Group 2 Dept Proposal Effort

Bret	Engelkemier
Todd	Fouts
Shawn	Holland
Alan	Hope
John	Kim
Jackie	Kostoff
Herbert	Schonken
Dave	Snyder
John	Tzioufas

#### Group 3

Darrell	Ahne
Deidre	Caldwell
Ken	Davis
Susan	DelMedico
Ed	Heinen
Shoeb	Ismail
Carrie	Sumner

#### Group 4

Jim	Bock
Bob	Buente
Ronald	Gliane
Steven	Hermann
Michael	LeDocq

Mark Mueller  
John Selmarten

**Group 5**

Beth Baird  
Cliff Helfrich  
Chuck Martin  
Kevin Powers  
Steven Staats  
Sonal Thakar  
Gene Wagner

**Group 6**

Jeffrey Berg  
Richard Gianvecchio  
John Hedrick  
Ernie Janensch  
David Quinn  
Dan Quitno  
Rommel Villalobos

**Group 7**

John Beirne  
Glen Fermoyle  
Joe Fittanto  
Eddie Goletz  
Shawn Murphy  
David Schafer  
Steve Woods

**Group 8**

Aaron Fundich  
Stuart Greenfield  
John Kane  
Hong Soo Kim  
Jerry Rauwolf  
Karl Stevens  
Chris Higgins

**Appendix C**  
**Request for Proposal**  
**for a**  
**Logistics Resupply and Emergency Crew Return System**  
**for Space Station Freedom**

**University of Illinois at Urbana-Champaign**  
**Aerospace Vehicle Design Course--AAE 241**

**Spring 1989**

**I. OPPORTUNITY DESCRIPTION**

Sometime in the middle to late 1990s, if all goes according to plan, Space Station Freedom will allow the United States and its cooperating partners to maintain a permanent presence in space. Acting as a scientific base of operations, it will also serve as a waypoint for future explorations of the moon and perhaps even Mars.

Systems onboard the station will have longer lifetime, higher reliability, and lower maintenance requirements than seen on any previous space flight vehicle. Accordingly, the station will have to be resupplied with consumables (air, water, food, etc.) and other equipment changeouts (experiments, etc.) on a periodic basis. Waste material and other products will also have to be removed from the station for return to earth. The availability of a Logistics Resupply Module (LRM), akin to the Soviet's Progress vehicle, would help to facilitate these tasks.

Riding into orbit on an expendable launch vehicle, the LRM would be configured to autonomously rendezvous and dock with the space station. After the module is emptied of its cargo, and waste material offloaded back into it, the module would begin its descent to a recovery point on earth.

LRM's could be configured in a variety of forms depending on the type of cargo being transferred. Such a vehicle might also serve double duty as a crew return capsule. Depending on size, a pressurized LRM could bring one or more crewpersons requiring immediate return back to earth.

**II. PROJECT OBJECTIVE**

The project objective is to develop a conceptual design for the system required to perform a logistics resupply mission to space station.

In addition, the design must allow for the use of a logistics module as a crew emergency return capsule to bring astronauts back to earth from the space station. An attachable orbital transfer propulsion subsystem may be used to carry supplies/crew/equipment to various orbiting platforms.

The system's performance, weight, and cost are very important to the acceptance of this type of mission, so approaches should be taken that optimize these parameters in design tradeoffs. The system should be reliable, easily operated, and reusable. It should use off-the-shelf hardware where available, but should not use materials or techniques expected to be available after 1994.

### **III. PROJECT GUIDELINES**

A thorough preliminary design study will be conducted to determine major design issues, establish the size of, define subsystems for, and describe the operation of a logistics resupply system that satisfies the following requirements:

1.) The system will consist of three primary components: logistics resupply capsule(s), space station docking adapter, and orbital transfer propulsion subsystem.

2.) The following subsystems are identified for the purposes of system integration:

- a.) Reentry and Recovery System
- b.) Structure (incl docking adapter, materials, design)
- c.) Power and Propulsion
- d.) Attitude and Articulation Control
- e.) Command and Data Control (incl. automated rendezvous and docking)
- f.) Life Support and Crew Systems
- g.) Mission Management, Planning and Costing

3.) The system's components and payload will be delivered to orbit on an expendable launch vehicle. The extent of shuttle support should be identified and minimized. Vehicle components must be able to be returned to earth in the space shuttle bay.



4.) Nothing in the system's design should preclude it from performing several possible missions, carrying vastly different payloads to the space station.

5.) The system will have a design lifetime of six years, but nothing in its design should preclude it from exceeding this lifetime.

6.) The vehicle will use the latest advances in artificial intelligence where applicable to enhance mission reliability and reduce mission costs.

7.) All vehicle components will operate under positive space station control at all times.

8.) The design will stress simplicity, reliability, and low cost.

9.) For cost estimating and overall planning, it will be assumed that four logistics resupply modules will be built. Three will be flight ready, while the fourth will be retained for use in an integrated ground test system.

#### **IV. ORAL MIDTERM PROPOSAL RESPONSE REQUIREMENTS**

The technical proposal is the most important factor in the award of a contract. As listed on the AAE 241 Schedule of Events, an oral midterm presentation is required. This presentation will serve as a proposal response outlining the approach to be taken and specific trade studies leading to the final design. While it is realized that all of the technical factors cannot be included in advance, the following should be included in the oral presentation:

1. Demonstrate a thorough understanding of the Request for Proposal (RFP) and Preliminary Design requirements.

2. Describe the proposed technical approaches to comply with each of the requirements specified in the RFP. Clarity, and completeness of the technical approach are primary factors in the evaluation of the proposals.

3. Particular emphasis should be directed at identification of critical, technical problem areas. Descriptions, sketches, drawings, method of attack, and discussions of new techniques should be presented.

## **V. FINAL DESIGN REPORT REQUIREMENTS**

The Final Design Report will contain all information obtained or developed for the design of Logistics Resupply and Emergency Crew Return System. It should be specific and complete. While it is realized that all of the technical factors cannot be included in advance, the following should be included in the final design report:

1. Demonstrate a thorough understanding of the Request for Proposal (RFP) and Preliminary Design requirements.
2. Describe the technical approaches used to comply with each of the requirements specified in the RFP. Legibility, clarity, and completeness of the technical approach are primary factors in the evaluation of the final design. Spelling and proper use of the English language are also important.
3. Particular emphasis should be directed at identification of critical, technical problem areas. Descriptions, sketches, drawings, method of attack, and discussions of new techniques should be presented in sufficient detail to permit engineering evaluation of the proposal. Exceptions to the proposed technical requirements should be identified and justified.
4. Include sensitivity analyses and tradeoff studies performed to arrive at the final design.
5. Provide an implementation plan for production of the final product.

## **VI. BASIS FOR EVALUATION**

### **1. Technical Content**

This concerns the correctness of theory, validity of reasoning used, apparent understanding and grasp of the subject, etc. Are all major factors considered and a reasonably accurate evaluation of these factors presented?

### **2. Organization and Presentation**

The effectiveness of the design report as an instrument of communication is a strong factor in evaluation. Organization of the final design report, clarity, and inclusion of pertinent information are major factors.

### 3. Originality

If possible, the design report should avoid standard textbook information and show independence of thought or a fresh approach to the project. Does the method and treatment of the problem show imagination?

### 4. Practical Application and Feasibility

The group should present conclusions or recommendations that are feasible and practical, and not merely lead the evaluators into further difficult or "show-stopping" problems. Is the project realistic from a cost standpoint?

## VII. FINAL DESIGN REPORT OUTPUT REQUIREMENTS

Final design project summaries will be submitted to NASA as required by the University of Illinois - NASA Advanced Design program grant. Additionally, the results of AAE 241 projects will be documented in a paper to be submitted to an appropriate forum.

Group final design reports will consist of a clear, concise, and thorough description of the overall design, its major features, and operational capabilities. It will illustrate any special or unique features with clearly labeled diagrams inserted in the text. It will explain and justify options selected to resolve the primary design issues. Students are encouraged to use original and innovative approaches so long as they meet or exceed the design requirements. The following are minimum output requirements:

1. One copy of the final design report will be submitted. It must bear the signatures, names, and student ID numbers of the project leader and design analysts within the group. Designs that are submitted must be the work of the students, but guidance and information may come from outside sources and should be accurately referenced and acknowledged.

2. Final design reports should be no more than 100 double-spaced typewritten pages (including graphs, drawings, photographs, and appendices). Equations related to the final design analysis shall be placed in an appendix at the end of each subsystem section.

3. Outline of the mission sequence of events, including, but not limited to:

- a.) Timeline of ground processing activities.
- b.) Crew evacuation and recovery timeline.
- c.) Integrated logistics module schedule.

4.) A table correlating the primary design issues, related design requirements, options considered, preferred option, and rationale for the option selected. This will not supplant, but summarize, the discussion of trades in the text.

5.) Design concepts, including comparison of options considered, major component weights, and total subsystem weights, for the subsystems identified above (where applicable).

6.) Overall drawings showing the layout of the system and its component subsystems. The drawings should be to scale and show major dimensions, the location of major elements of each of the subsystems, and be clearly labeled.

7.) Top-level program cost estimates and schedule including major milestones for development, testing, and engineering activities.

8.) A scale model of the major system components will be built and displayed during the final report. These models will also serve as the centerpiece of the University of Illinois' static display at the NASA/USRA 1989 Summer Conference.

## **VIII. SOURCES OF REFERENCE MATERIALS**

Some reference material required to carry out the design will be provided in the form of paper hardcopy, lectures, and electronic media where applicable.

IX. CALENDAR OF EVENTS

Significant activities, homework required, and dates for submission of proposal related materials are presented in the accompanying document entitled "Schedule, AAE 241, Spring 1989."