2005/2006 AIAA FOUNDATION Undergraduate Team Space Design Competition

I. RULES

1. All groups of 3 to 10 undergraduate AIAA branch or at-large Student Members are eligible and encouraged to participate.

2. The final design report for this competition will be submitted electronically. A Microsoft Word 2002 or Adobe PDF file (10MB size limit) of the submittal shall be e-mailed to: tetherproject@cfa.harvard.edu. Questions related to report submission can be directed to this address. One hardcopy of the signature sheet shall be submitted by the team to the AIAA Student Programs Department along with a disk/CD in PC format (i.e., if using Mac, save on PC formatted media) of the proposal (see address in Section II). The signature sheet must bear the signatures, names, and student numbers of the project leader and the AIAA Student Members who are participating. Designs that are submitted must be the work of the students, but guidance may come from the Faculty Advisor and should be accurately referenced and acknowledged.

3. Design projects that are used as part of organized classroom requirement are eligible and encouraged for competition.

4. The prizes shall be:
   First place - $2,500;
   Second place - $1,500;
   Third place - $1,000.

   Certificates will be presented to members of the winning design team for display at their university and a certificate will also be presented to each team member and the faculty project advisor. One representative from the first place design team will be expected to present a summary design paper at the AIAA Space 2006 Conference. Reasonable airfare and lodging will be defrayed by the AIAA Foundation for the team representative.

5. More than one design may be submitted from students at any one school. Project reports shall be no more than (if it were printed) 100 double-spaced typewritten pages (including all graphs, drawings, photographs, and appendices) on 8.5” x 11.0” paper and typeset shall be no smaller than 10 pt. Times New Roman. Up to five of the 100 pages may be foldouts (11” x 17” max) as required to clearly present graphs and drawings.

6. If a design group withdraws its project from the competition, the team chairman must notify the AIAA Student Programs Department immediately!

II. SCHEDULE AND ACTIVITY SEQUENCES

Significant activities, dates, and addresses for submission of proposal and related materials are as follows:

A. Letter of Intent – 17 Mar 2006
B. Receipt of Proposal – 9 June 2006
C. Announcement of Winners – Aug 2006

Groups intending to submit a proposal must submit a Letter of Intent (Item A), with a maximum length of one page to be received with the attached form on or before the date specified above, at the following address:

Student Programs Liaison
AIAA Student Programs
1801 Alexander Bell Drive
Suite 500
Reston, VA 20191-4344

The finished proposal must be received at the same address on or before the date specified for the Receipt of Proposal (Item B).

III. PROPOSAL REQUIREMENTS

The technical proposal is the most important factor in the award of a contract. It should be specific and complete. While it is understood that all of the technical factors cannot be included in advance, the following should be included and keyed accordingly:

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

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

3. Particular emphasis should be directed at identification of critical, technical problem areas. Descriptions, sketches, drawings, systems analysis, method of attack, and discussions of new techniques should be presented in sufficient detail to permit engineering evaluation of the proposal. Exceptions to proposed technical requirements should be identified and explained.

4. Include tradeoff studies performed to arrive at the proposed design concept.

5. Provide a description of any automated design tools used to develop the design.

IV. BASIS FOR JUDGING

1. Technical Content (35 points)

   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 (20 points)

   The description of the design as an instrument of communication is a strong factor on judging. Organization of written design, clarity, and inclusion of pertinent information are major factors.

3. Originality (20 points)

   The design proposal should avoid standard textbook information, and should show the independence of thinking or a fresh approach to the project. Does the method and treatment of the problem show imagination? Does the method show an adaptation or creation of automated design tools?

4. Practical Application and Feasibility (25 points)

   The proposal should present conclusions or recommendations that are feasible and practical, and not merely lead the evaluators into further difficult or non-solvable problems. Is the project realistic from a cost standpoint? Does the presentation include environmental impact studies (where applicable) and analysis of the function of the design in or for society?

V. REQUEST FOR PROPOSAL

New Decelerator System for Capsules Reentering from Deep Space

1. Opportunity Description

During this decade and the following one, several missions will return samples from various locations of the Solar system. Genesis has already returned a sample of solar wind particles; Stardust is in orbit to collect samples from the coma of the Wild-2 comet; Muses-C will be the first mission to return a sample of an asteroid; the Mars Sample Return will collect samples of the Martian surface and return them to Earth; the Comet Nucleus Sample Return will drill into a comet and return a sample of the nucleus [Refs. 1, 2, 3]. All these missions have in common a direct entry (i.e., hyperbolic approach trajectory) into the Earth's atmosphere at velocities of 11 km/s and greater. The challenges are to design capsules and deceleration systems that are simple, low-mass, autonomous, and reliable. All the missions mentioned above utilize a ballistic reentry with an ablative shield on the capsule for heat dissipation/protection in the entry phase and supersonic and subsonic parachutes during the terminal phase. More recently, tethered ballutes have been proposed for decelerating capsules during entry in the upper atmosphere. We think that an alternative for decelerating the reentering capsule at high altitudes can be provided by a long trailing tether (without ballute) and we invite the student teams to explore this alternative [Ref. 4].

2. Project Objective

Sailors have known for centuries that in high seas and very strong winds the safest way to navigate a sail boat is to draw a very long line into the water from the stern and head downwind. Because of the large area of the rope in the water, the trailing line exerts a substantial drag and also prevents the boat from turning sideway into the waves and, possibly, capsizing.

A similar concept could be used to decelerate space capsules, like Genesis, when reentering the Earth's atmosphere to bring back the samples collected during their journey into space. A several kilometers long tether of suitable material deployed from the capsule well before atmospheric entry will substantially slow down the capsule at altitudes well above the dense atmosphere (note that 125 km is the NASA conventional reentry altitude where the atmosphere starts to be significantly dense) and make the capsule go through the reentry phase at a much reduced speed (see Ref. 4 for a study on a long tether decelerator to reenter capsules from Low Earth Orbit). The end benefit is that the peak heat load on the capsule itself is drastically reduced while the tether takes most of the heat load over a longer time span that starts before the conventional reentry phase. Moreover, the exposed surface of the tether is much larger (because of its length) than the exposed surface of the reentry capsule and, consequently, its temperature is lower than the peak temperature of a capsule reentering without a trailing tether.

3. Design Requirements And Constraints

The design project will consist in using the return-to-Earth profile of a deep-space reentry capsule like Genesis (see Fig. 1) to design a tether-based deceleration system to significantly reduce the maximum temperatures on the capsule and the decelerator itself.

While the tether is intended to be deployed in the earliest phases of reentry when the vehicle is exposed to the free-molecular flow, lower speed supersonic and subsonic parachutes should also be included to allow safe terminal descent and landing of the capsule via touch-down or capture in mid air.

Fig 1 Genesis reentry capsule.

The design team will be required to:

- trade-off decelerator concepts (e.g., short tethers with ballutes vs. long tethers without ballutes but with a tip mass to facilitate tether deployment) and compare the performance to a ballistic reentry without tethers;

- develop a tether-decelerator preliminary design inclusive of selection of suitable supersonic and subsonic parachutes;

- provide a timeline of key events including tether and parachute deployments;

- evaluate tether deployment strategies before entering the atmosphere (assume a maximum tether exit speed from the deployer of 20 m/s) and identify required hardware, inclusive of the tip mass;

- evaluate thermal control techniques which involve the selection of an appropriate absortivity/emissivity ratio for the tether and selection of a heat-resistant tether material;

- evaluate reentry trajectory profiles, starting from the time when the tether is fully deployed, and compute simplified thermal balances for tether and capsule to estimate temperatures.

- give consideration to a safe way for tether disposal before opening the parachutes. Answer the question: what is the risk of having a tether surviving atmospheric reentry? [Ref. 9]

- propose alternative concepts or designs if and where appropriate.

Design goals/merits are as follows:

- Work within existing technology boundaries or realistic improvements of present technology;

- Design for low cost, simplicity, robustness, and system autonomy.

- Additional design merits are low mass for the decelerator system, and strongly-reduced maximum temperature (or peak heat load) for the capsule with respect to a ballistic reentry.

This design challenge shall be approached by:

- forming a team with multi-disciplinary expertise;
- stressing system engineering;
- focusing on trade off analyses;
- finding engineering solutions that are within the state of the art in technology.

In the following, we provide design constraints, numerical details, and a reference hyperbolic trajectory (Fig. 2) for Earth’s approach and entry into the atmosphere that approximates Genesis' data at *its nominal entry altitude of 125 km with ballistic reentry* [Ref. 1].

Reentering mass: 200 kg

Capsule's frontal area: 1.5-m diameter

Peak Deceleration: < 30 Earth's g

Maximum temperature of Genesis' heat shield: ≈2500 °C.

Peak heat rate on Genesis capsule: ≈750 W/cm^2.

Entry inertial velocity at an altitude of 125 km: 11.04 km/s

Entry flight path angle at 125 km: -8.2 deg.

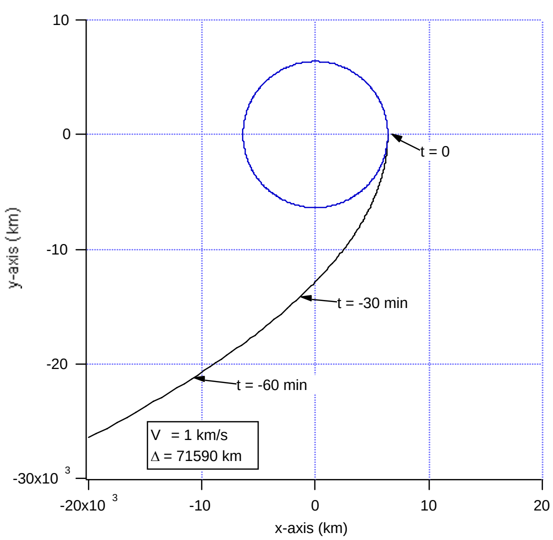

Fig. 2 Reference trajectory for Earth's (in blue) hyperbolic approach.

The values of Genesis' atmospheric entry are shown for comparison purposes. The trailing tether, deployed well in advance of the nominal atmospheric altitude, will provide a lower entry speed and a different flight path angle than for a ballistic entry. One of the goals is to design a tether decelerator that produce entry conditions which are substantially more favorable than Genesis'.

The reference approach trajectory should be used by the design teams to provide a timeline of events before entry into the Earth's atmosphere (e.g., during tether deployment). The trajectory was derived by assuming asymptotic values as follows:

- Velocity at infinity: $V_\infty = 1$ km/s
- Distance offset (between asymptote and Earth's center): $\Delta = 71590$ km.

After the tether is fully deployed, each team should compute a trajectory that is consistent with the specific sizing of the tether/decelerator system and utilize that trajectory for the necessary thermodynamic computations.

4. Data Requirements

In the final report, the teams are expected to:

- summarize assumptions and approaches
- describe trade off analysis
- identify design drivers
- justify selected design
- define/describe system architecture and the driving requirements
- provide drawing of design concept
- describe the operational sequence
- identify needed technology development
- provide a preliminary cost evaluation

5. Additional Contacts, Data And References

All questions pertaining to this RFP should be directed by email to TetherProject@cfa.harvard.edu. All questions and answers will be posted on the AIAA Space Tethers Technical Committee web site, which can be accessed through the AIAA homepage at www.aiaa.org. Click on "Inside AIAA" and then on "Technical Committees", and scroll down to the Space Tethers Technical Committee homepage. Questions and answers regarding this RFP will be posted under the "Student Design Competition" menu selection.

References:

Genesis' mission data

1) *Genesis Sample Return,* press Kit, September 2004
2) Desai, P. N., and F. McNeil Cheatwood, *Entry Dispersion Analysis for the Genesis Sample Return Capsule*, AAS paper 99-469, AAS/AIAA Astrodynamics Specialist Conference, Girdwood, Alaska, 16-19 August 1999.
3) Desai, P. N., R.A. Micheltree, and F. McNeil Cheatwood, *Sample Return Missions in the Coming Decade*, IAF paper 00-Q.2.04, 51st International Astronautical Congress, 2-6 October 2000, Rio de Janeiro, Brazil.

Papers relevant to space tethers

4) Krischke, M., E.C. Lorenzini,and D. Sabath, "A Hypersonic Parachute for Low-Temperature Reentry." Acta Astronautica, Vol. 36, No. 5, pp. 271-278, 1995.
5) Arnold, D. *The Behavior of Long Tethers in Space,* The Journal of Astronautical Sciences, Vol. 35, No. 1, 3-19, 1987.

Usefull textbooks

6) Wiesel, W.E., "Spaceflight Dynamics." McGraw Hill, 1989.
7) Bate, R.R., Mueller, D.D., and White, J.E., "Fundamentals of Astrodynamics." Dover Publications, Inc. 1971.
8) Regan, F.J., "Re-entry Vehicle Dynamics." AIAA Education Series, 1984.

Relevant web sites

9) Delta-UTEC web site on project YES2: http://www.yes2.info/.
10) AIAA Survivability Technical Committee web site: http://www.aiaa.org/tc/sur/index.html

Intent Form

2004/2005
AIAA FOUNDATION
Undergraduate Team Space Design Competition
Request for Proposal: **Design of a International Space Station Crew/Cargo Transfer Vehicle**

Title of Design Proposal: ____

Name of School: ____

Designer's Name	**AIAA Member #**	**Graduation Date**	**Degree**
____________ Team Leader	____________	____________	____________
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In order to be eligible for the 2005/2006 AIAA FOUNDATION Undergraduate Team Space Design Competition, you must complete this form and return it to the AIAA Student Programs Liaison ***before 17 March 2006***, at AIAA Headquarters, along with a one-page "Letter of Intent" as noted in Section II, "Schedule and Activity Sequences." For any nonmember listed above, a student member application and member dues payment should also be included with this form.

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Signature of Faculty Advisor	Signature of Project Advisor	Date