Satellite Communications Class Project:
Lunar Bread Crumbs

ECE 6390 – Fall 2009

Synopsis:

The *National Aeronautics and Space Administration* (NASA) recently awarded your up-start company a Phase I *small-business innovative research* (SBIR) grant to design a Lunar Positioning System for astronauts on moon walks (in anticipation of returning to the moon with extensive scientific missions next decade). The field of applicants for this next round of funding is competitive, with 7 other private companies also competing for a lucrative, multi-year Phase II contract. See the solicitation attached to this problem statement.

Team-Member Assignments:

I will assign 8 teams with 4-5 members each to constitute a "company". Once formed, the teams must elect a team-leader, choose a company name, and submit an 80 x 80 pixel icon for their web link. I expect everyone to contribute to the final proposal and will solicit internal rankings of team-member efforts.

System Components:

Due to the multiplicity of talents within each group and the "systems"-nature of the class, *all* aspects of the mission design should be explored in the final proposal. Communication/location systems should receive the most design focus, but the final project should address all of the following systems:

- Communication Systems – antennas, RF hardware, modulation, spectral usage, peak data output, etc.
- Location System – location estimate accuracy, error sources, RX antenna ***measurement***
- Power Systems – power source, peak power output, estimated lifetime, etc.
- Budget and Timeline – total research and development costs broken into materials, equipment, supplies, people costs, space resources, and other miscellaneous costs; include a small-company "overhead" of 30% for all personnel costs; include milestones listed on a Gantt chart; project a per-mission cost of using this system for a lunar excursion.

This list is not necessarily exhaustive. The level of detail for each system is left up to the groups. However, increased descriptions will enhance the competitiveness of your design. *Verbose* descriptions will degrade the competitiveness of your design.

Deliverables:

You must prepare a concise, well-written technical report detailing your team's mission design. The report should be in html-format with all files submitted in-class on a CD or through e-mail (e-mail submissions are strongly preferred; they must be ZIPped and are only possible for files less than 20 MB total). Projects must be submitted by noon on 8 December 2009. Late projects will not be accepted.

Grading:

Your final proposal will be *competitively* graded on cost, functionality, and feasibility – as if I were making the Phase II funding decisions for this SBIR program. The proposals from the class teams will be ranked against one another and assigned a base score of 100% - 3(n-1) where n is the integer ranking (1-8). Thus, first place will receive a base score of 100%, second place will receive 97%, third place will receive 94%, and so on. Deductions from these base scores will then be made based on the following areas: Completeness, Technical Writing, Professional Content, Research/References, and Conciseness. Groups may also barter points with one another for use of an antenna design (should the prototype turn out to be a dud).

Each team member may also receive a small, variable downward adjustment to their individual project scores based on internal rankings of contribution and effort. I will also offer +5% bonus points to superlative proposals in the following categories:

1) Best Technical Writing
2) Creative Use of the Web
3) Most Novel Engineering Design or Concept

Late projects will not be accepted. All projects will be posted on the web, unless the team members collectively object and notify me.

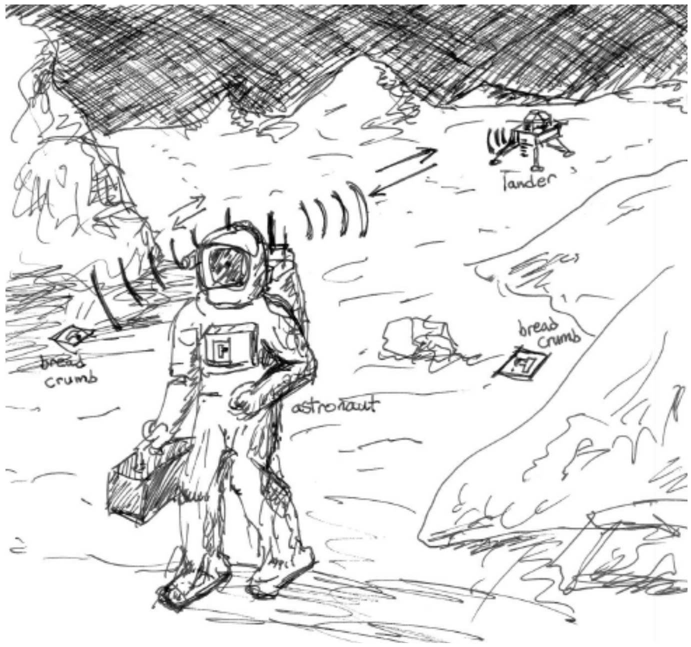
Video/DL Student Grading:

Distance-Learning students will perform the same project individually (no groups) with the following changes to the grading/submission scheme: 1) a shorter PDF or DOC write-up on your proposed design is expected (no website required), 2) no penalties or bonuses in base scoring of the assignment, 3) no antenna design component (assume all tagging antennas are 0 dBi isotropic).

NASA093-007 TITLE: <u>Lunar Bread Crumbs</u>

TECHNOLOGY AREAS: Space Communications, Radiolocation, Antennas, RF engineering

OBJECTIVE: Design a radiolocation system for astronauts on moonwalk based on the “bread crumb” concept.



DESCRIPTION: Next decade, the US plans to return to the moon and perform new science missions and moon walk explorations. One of the lessons learned in previous Apollo missions was the difficulty in performing rover and astronaut excursions in the rugged, bright-white terrain of the moon; it is extremely easy for astronauts to lose their way in this featureless environment filled with valleys, hills, and craters. Earth location systems such as GPS are not available on the moon and too costly to build. However, NASA is extremely interested in testing a new “bread crumb” technique for tracking astronauts that travel through regions around their lunar lander. Much like Hansel and Gretel’s bread crumbs, an astronaut on excursion would drop very small, disposable RF identification tags that operate on the principle of backscatter modulation. The astronaut’s suit would contain a low-powered reader that could measure reflected tag data and coherent signal strength (amplitude and strength) in proximity of these tags as well as a signal sent from the lunar lander, using this information to navigate the lunar terrain.

The company is expected to design the antenna, RF, and communication systems for the lander-to-astronaut link and the astronaut-RF tag link, as well as the location algorithm. Several electrical conditions must be imposed on the system:

- All RF tag antennas are presumed to be connected to ideal, passive RF integrated circuits that require -20 dBm of RF power to turn-on. These antennas may be treated as 0 dBi average-gain isotropic antennas in the analysis and cannot have more than 3% bandwidth.
- You must design, build, and measure a prototype omnidirectional transmit antenna for the lunar lander. Whatever range-measured characteristics this antenna exhibits (gain and bandwidth), these are the parameters that must be used in the link design for the group’s project. You may assume that the astronaut-suit-mounted antenna has identical gain and bandwidth parameters as your lander antenna.
- FCC rules do not apply on the moon, so there are no regulatory limits on power and operating frequency. However, keep radiation safety and power source limitations under consideration. The frequency of operation must lie between 1-3 GHz.

- You must have a data link with at least 100 kbps continual data support from astronaut to lander (higher rates will make your project more competitive). It must work in non-line-of-sight conditions of up to 2 kilometers, which means that you will have to formulate a reasonable propagation model for the lunar surface.

The system technical description must include (a) the RF components and modulation for the RF tag reader and astronaut-to-lander link, (b) an estimate of accuracy for the system, and (c) operational details of the location algorithm along with any deployment rules or practices that the moon-walker must follow.

PHASE I: Deliverables include (a) a browse-able, web-based technical report summarizing a design for the bread-crumb system, (b) measured prototype of an electrically small antenna for use in the tag. Link budget and location performance statistics in your technical report must be based on this measured prototype antenna. Competitive rankings will consider 1) cost, 2) predicted accuracy and performance, and 3) thoroughness and believability in your analysis in roughly equal proportions.

REFERENCES:
1. T. Pratt, C. Bostian, T. Allnutt, *Satellite Communications*, 2nd edition, Wiley, 2002.

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