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Private, Commercial and Student-oriented Low-cost Deep-Space Missions: A Global Survey of Activity

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Abstract

Primary mission objectives for most deep-space missions to date have emphasized acquiring scientific data and expanding our understanding of the solar system; some contemporary missions target advanced technology demonstration with science as a secondary objective. All missions so far have been sponsored by one or more government agencies, organizations or consortia.

Now a new class of deep-space missions is emerging: those motivated and sponsored by private, commercial and student-oriented interests and organizations. Several such missions — the first to actually be executed — are likely to occur in the 2000-2005 period. Underlying motivations for these unconventional ventures are summarized.

For context, this survey starts with similar activities during 1970-95. *Lunar Prospector* is perhaps the most visible success story here: it was initially a privately financed venture before being selected as a NASA *Discovery* mission. Why few of these early efforts succeeded in meeting their objectives — and why some did — is explored.

Next, a worldwide snapshot of current activity in this arena is provided, highlighting the most visible and credible developments, most of which are in the U.S. and Europe. Principal mission attributes, team composition and unconventional features are summarized for each. All are still in the conceptual or preliminary design phase, but least one (NEAP is expected to move into development and implementation this year.

Implications of this emerging trend to the conventional space-science mission community are addressed. Included here are the continued need for science instruments and scientific talent, the prospect of expanding the array of space technologies and infrastructure, new teaming relationships and funding mechanisms, and various cost and risk issues.

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Motivations

The premise of this survey is that something significant is happening now to the deep-space arena. A new branch is emerging from the traditional government-sponsored mission lineage: one including private, commercial and student-oriented missions. (For the purposes of this discussion, *deep space* is defined as at lunar distance from the Earth and beyond, including the Earth-Moon and Earth-Sun libration points and near-Earth heliocentric orbits.)

The factors that make the thought of routine, low-cost *private* deep-space missions more plausible include progress with advanced space technology development and validation (including more focus on this in the NASA and

Japanese space-science programs), higher space equipment production and launch rates, near-term prospects for reductions in launch vehicle costs, advances in commercial electronics and software, and increasing competence in the space mission community.

Augmenting these significant forcing functions are other factors:

- NASA's grip on deep-space activities (notably JPL's) is slowly loosening
- Government budgets for space — NASA's space science budget in particular — are admittedly precarious.
- Creative and powerful teams are being formed among smaller space and technology firms and organizations
- Individuals working in 'big' space industry and space science are welcoming a change to the smaller environment
- University-based and non-profit space programs are advancing, with increasing capabilities and expanding interests
- Atypical investors and other nations are looking for opportunities to get into the deep-space game
- There is a much better scientific appreciation for the solar system and what's in it, particularly regarding the Moon, Mars, asteroids [1] and comets
- Market-driven economics is being validated worldwide, encouraging its application to new sectors of the global economy — and the private sector is starting to notice.

Some entrepreneurs and investors have concluded that there is potential profit to be made in this emerging high-tech field — and not strictly just to conduct science or validate advanced technology. So they are starting to act on an array of innovative, unconventional and often risky ideas.

Context: 1970-1995

1970 appears to be when this trend started in a credible way — when a few initiatives actually made some progress or had an impact — though some earlier examples could undoubtedly be cited. (Certainly for years science fiction authors and artists presented the basic vision, at least.) For example:

Harvest Moon Project, New Worlds Co., 1970-72. In October, 1970 a U.S. organization, the Committee For the Future (CFF), proposed conducting a privately financed venture that would use surplus, donated *Apollo* hardware for an international, perhaps civilian human mission to perform experiments and demonstrations that would lay the groundwork for later colonization and economic exploitation of the Moon [2]. It involved placing the lunar lander and crew (including a Soviet cosmonaut!) at Hadley Rille, the scenic *Apollo 15* site, where they would deploy a prototype lunar garden, robot rover, laser communications relay station and a small telescope. The CFF formed the New Worlds Company in early 1971 to implement the ambitious project. Following good progress during the subsequent year, NASA informed the CFF that the remaining lunar landers had been cannibalized for parts and plans quickly faded.

Space Studies Institute (SSI), 1977-present. This popular Princeton-based space research organization founded by physicist Gerard O'Neill can be largely credited with popularizing the grand vision of extensive space resource utilization and manufacturing and human space colonization, using lunar and asteroidal resources and space solar power [3]. One of SSI's principal goals is to get the private sector into the space arena. O'Neill is credited with a series of very successful and catalytic conferences on space manufacturing

[4] which spawned numerous research and analysis efforts that continue today [5].

The World Space Foundation (WSF), 1978-1998. This California-based space research and space advocacy organization is modeled after the National Geographic Society. It sponsored or participated in research efforts focused on observational searches for near-Earth asteroids, space technology development, lunar and Mars exploration, space resource utilization and planetary science. In 1982 the WSF initiated a privately funded project to develop and launch a solar sailing demonstrator spacecraft — the ultimate goal being Earth escape and possibly a lunar gravity assist to deep space — and various forms of corporate and organizational support followed [6]. The WSF design was the winning entrant for the Americas region in the planned 1992 Columbus 500 Space Sail Cup event (see below). The organization ceased operation in early 1998 and its asteroid search and solar sail projects have been transferred to The Planetary Society.

The Viking Fund and Delta Vee, Inc., 1979-82. This short-lived California-based effort was actually the first to accomplish private funding of a deep-space mission — partially, anyway. From 1979-81 founder Stan Kent operated The Viking Fund, a "do-it-yourself space program", in collaboration with the San Francisco Section of the American Astronautical Society and Bay-area volunteers. The Fund's principal purpose was to "Feed a Starving Robot ... and a Starving Space Program": to raise $1M in private money to support the continued analysis of Viking-1 lander imaging and weather data for a decade [7, 8]. Over $100,000 was eventually contributed to NASA during the 18-month effort. NASA used the funds to create an albedo map of Mars, to analyze a two-year backlog of Martian weather data, and to sponsor a special journal issue dedicated to Mars [9].

Inspired by the Viking Fund's success, in late 1980 Kent formed a non-profit organization to expand the theme: Delta Vee, Inc. In 1981 — while the Shuttle Program was conducting its first mission — Delta Vee announced The Halley Fund, challenging the U.S. public to "Come Explore a Comet" [7]. Its principal aim was to help fund a NASA-sponsored mission to the popular comet. Though fundraising for this initiative was similarly effective, NASA was not authorized to conduct the 1985-86 Halley mission, so Delta Vee's plans floundered. (Some 'credit' was attributed to the Halley Fund for <u>not</u> getting this authorization, since some in the U.S. Congress saw the strong private support for the mission as an excuse not to fund it with taxpayer money [10].)

In 1981, Delta Vee initiated a low-level space technology research program addressing orbiting solar reflectors, asteroid capture and 'wafer' rockets, and also co-sponsored the first Case for Mars Conference [11].

The Planetary Society (TPS), 1980-present. This U.S. organization was founded by space scientists Carl Sagan and Bruce Murray and JPL space mission engineer Louis Friedman to encourage the exploration of the solar system and the search for extraterrestrial life. While the organization does not believe that private organizations can carry out solar system exploration missions, they do help to seed future missions by supporting and helping to devise novel ideas for research and development. For over ten years, TPS has supported a radio search for extraterrestrial intelligence (SETI). It has helped develop and test Mars balloon and Mars rover prototypes, helped fund observations of asteroids and comets, conducted studies of human space flight missions to the moon and Mars as well as robotic missions to near-Earth asteroids and an international mission to Pluto. It is now developing a Mars microphone to be integrated with the 1998 Mars Polar Lander vehicle [12].

The Space Foundation, 1983-88. This Houston-based organization supported by Peat, Marwick, Main & Co. initiated "Space Business Roundtables" around the U.S. in a fairly successful attempt to get some meaningful dialog started between the emerging commercial space community (addressing business concepts beyond the established commercial communications satellite arena) and others from the worlds of finance, government policy, insurance, law and non-aerospace advanced technology. The Houston Roundtable in particular was credited with fostering ventures such as Orbital Sciences, Inc. and Space Industries, Inc. [13].

Columbus 500 Space Sail Cup, 1989-92. This ambitious concept was proposed by the Christopher Columbus 500 Quincentenary Jubilee Commission. In conjunction with the 1992 International Space Year, it called for the "sail of the century": an interplanetary regatta to Mars, using solar sail technology to propel spacecraft supplied by countries from Europe, the Americas and Asia — and launching on Columbus Day, ideally. One original stipulation of the competition (later rescinded) was that no government funds would be allowed on any team's effort. The race was expected to be from the Earth to the Moon to Mars over one to five years, and intermediate engineering-related milestones were postulated to measure progress. By late 1990 a field of a dozen or so possible entrants from around the globe necked down to three: the WSF design for the Americas, a combined French/Spanish entry for Europe and one from Japan. A combined Ariane-4 launch was baselined. Lack of technical performance and lack of funds caused the original regatta plan to unravel, but discussions continued for a few more years about launching on other rockets [14].

Lunar Polar Probe/Lunar Prospector, SSI, Omni Systems, Inc., and Lunar Exploration, Inc., 1985-1993. In mid-1989 SSI announced its intent to launch a lunar polar probe in 1992 as part of the International Space Year [15]. A surplus *Apollo* gamma-ray spectrometer — in storage at JPL — was baselined as the principal science instrument. NASA agreed in principle to grant the use of the GRS later that year. By mid-1990 a conceptual small spacecraft design (including full-scale mockup) and mission plan was in place and serious launch vehicle candidates were identified, including a Proton offer from the USSR. The project was renamed *Lunar Prospector*, and by this time a few additional science instruments had been baselined, targeting lunar ice, surface chemical properties and gravity-field mapping. By the end of 1990, the non-profit Lunar Exploration, Inc. (LEI) had been formed to execute the project and Alan Binder was named as the Principal Investigator and Project Manager [16]. LEI was seeking to raise over $10M in private funds to pay for the project, not including the launch nor lots of volunteered and donated resources. Binder and his team continued to market the Lunar Prospector plan during 1991 and 1992, with not quite enough success to execute. It eventually was proposed as a low-cost NASA *Discovery* mission in 1992 and was selected in early 1993 — the first Discovery mission to be selected competitively.

Large-scale lunar civil-engineering projects, 1985-1992. In 1986, Japan's Shimizu Corporation formed a Space Project Office, and in 1986 it initiated the "Lunar City 2050 Project", a postulated south lunar polar 'city' of some 10,000 inhabitants used to focus Shimizu's R&D efforts [17]. Shimizu spent non-trivial amounts of their internal funds investigating strategies for conducting commercial activities on the Moon. In the U.S., Bechtel formed a space projects office in the early 1990s to evaluate similar issues [18].

Clementine, BMDO/Naval Research Laboratory, 1996. This low-cost, lunar orbiting advanced technology demonstration mission represents a clear example of the trend away from NASA-only deep-space mission activities in the U.S. It was noticed by NASA, JPL, the space industry and Congress!

Near Earth Asteroid Rendezvous (NEAR), Johns Hopkins/Applied Physics Laboratory, 1995-present. For the first time in many years, an organization besides JPL was authorized to conduct a NASA deep-space science mission, reaffirming that a break from the past was occurring.

Blue Moon, U.S. Air Force Academy, 1995-96. One of the first serious deep-space mission proposals from the university community was this project, a GTO-to-lunar orbit concept [19]. Cadets assisted by a small group of instructors, mentors and space industry professionals developed a credible mission and system design and engaged in serious discussions with Arianespace about acquiring a ride on an Ariane 4 as a secondary payload. Ultimately, the project floundered in favor of other Earth-orbiting mission concepts.

This, then, is one view of the past. What about now?

Current Activity

We include here known, non-government-sponsored efforts worldwide *that appear to have a reasonable prospect* of continuing and being implemented in some way during 2000-2005. In some cases, details are purposely left vague to honor the proprietary nature of selected projects. (Because of the applied reasonableness filter, some current activities and organizations are not mentioned.) Contact information for each of these firms appears at the end of this paper.

NEAP and SpaceDev, Inc. The Near-Earth Asteroid Prospector mission is being developed by SpaceDev, a publicly owned company founded by retired computer entrepreneur James Benson in 1996, with a stated goal of being "the world's first commercial space exploration company" [20].

For several reasons, SpaceDev considers the NEAP mission to be a relatively straightforward deep-space mission to another solar system body compared to other options (including lunar missions) and thus is doing it first. Launching between early 2000 and early 2001 (depending on the chosen target), it is to rendezvous with either NEA 1983 BX3 or 1996 XB27, and, in Benson's words, "size it, characterize it and touch it". It will carry three SpaceDev-sponsored science instruments: a multiband camera and a neutron spectrometer on the main spacecraft and a 'DropCan'-mounted Alpha Proton X-ray Spectrometer, to be released upon arrival at the asteroid so it can passively land on the asteroid's surface to make composition measurements.

NEAP will also carry six additional customer-supplied instruments and DropCan packages (three each) for a fee, as specified on its price list. Revenue is derived from the fees for carrying this 'cargo', sales of science data sets from SpaceDev's own instruments, and sales of various forms of advertising and other rights. Prices for cargo delivery are $10-12M and the SpaceDev instrument data sets are $15M. The entire mission will be insured — a first for the deep-space arena. NASA has agreed that it will consider Discovery #6 mission-of-opportunity proposals in conjunction with the NEAP opportunity.

LunaCorp. Founded in 1989, LunaCorp plans to send two surface rovers to the Moon around 2000 or 2001. In the baseline plan, the rovers will undertake an ambitious traverse from near the *Apollo 11* landing site, past the *Surveyor 5*, *Ranger 8*, and *Apollo 17* sites, and then begin a search for the Soviet *Lunakhod II* rover. The mission's primary source of revenue will be public participation: people can pay to drive the rovers in theme-parks via telepresence. LunaCorp is working with the Robotics Institute at Carnegie Mellon University to prototype and build the rovers, and with the firm ViRtogo to produce an arcade telepresence experience (a prototype is described at www.lunardefense.com). Major support for development of the telepresence technology is anticipated from a large U.S. auto manufacturer [21]. Recent findings of water at the lunar polar regions *by Lunar Prospector* may enhance interest in LunaCorp's plans.

Lunar Research Institute, Lunar Exploration, Inc. *Lunar Prospector* scientist Alan Binder intends to continue a lunar research program with a series of commercial lunar missions, starting with three additional lunar orbiters (for completing the digital mapping of the Moon) and then a series of lunar landers [22]. Planning for this mission series will begin in earnest later in 1998.

Lunar Retriever. This is a lunar sample-return mission proposed by Applied Space Resources (ASR) of Long Island, New York. The small lander vehicle — also fully insured — would land in Mare Nectaris near the lunar equator, collect around 10 kg of lunar material, and return it to Earth to be sold to research institutions and private individuals, perhaps on the open market. ASR has a contract in place for a 2000-2001 launch on a Lockheed Martin Athena 2 launch vehicle and is presently engaged in mission design and fundraising.

Lunar Video Orbiter. This advertising-driven mission was proposed in 1996 by Lunar Enterprise Corporation (a subsidiary of Space Age Publishing) and International Space Enterprises (ISE), a San Diego firm. LVO would place a TV camera in lunar orbit by January 1, 2000, and return video of Earth risings and Moonscapes with an advertiser's product in the foreground.

Commercial Lunar Landers, International Space Enterprises. ISE has been formulating plans for a series of commercial lunar landing missions since 1992. They have formed a joint-venture company with Russia's Lavochkin Association, ISELA, to facilitate the application of proven Russian hardware and techniques to these missions. Two other Russian firms, Krunichev Enterprises and Zvezda, would respectively provide Proton launchers and soft-landing systems.

LunarSat. This concept grew out of a 1996 ESA Summer School project to design a spacecraft that would orbit the moon by the year 2000. About 50 young scientists and engineers at various universities throughout Europe are now working closely with ESA to design and build the <100 kg vehicle. The spacecraft will support ESA's Euromoon program by providing a high-resolution optical survey of the south pole of the Moon. (Though funding may likely come from ESA, the Project is largely a university-level effort and thus warrants inclusion in this list.)

Implications

What does all of this mean? We believe a few key observations can be made:

- It is clear from the list of current activity above that the Moon and near-Earth asteroids will be the most likely targets for mission attempts of the non-government type in the next five years or so.
- The existence of water ice at the lunar poles should help bolster interest and credibility for lunar missions, especially if NASA continues to show little interest in a lunar campaign.
- There will be a continued need for science instruments and scientific talent to support many of these missions
- These missions will expand the array of available space technologies and infrastructure, and should provide a variety of additional opportunities
- New teaming relationships and funding mechanisms are being pioneered which should lead to expanded capabilities and opportunities, particularly in the U.S.
- Most of these missions will cost less than $100M. These teams currently can't finance anything that costs more.
- Most if not all of these missions will be relatively risky, particularly in terms of cost and schedule. The insurance angle is an important and positive development.
- The space science community should expect to see — and should welcome — some mission concepts that might best be compared to 'barnstorming' stunts from the early days of aviation, e.g., media-driven missions. We should all encourage the proven techniques of market-driven economics to play out in this new arena.
- Things are happening quickly; expect interesting changes and developments on a monthly basis.

Conclusion

After a decades-long run-up, it appears that alternative, private-sector deep-space ventures are about to take off. The key ingredients to enable such activities — the knowledge, skill and rationale — exist for some types of missions, as they will for others to follow. Necessary resources will be found.

In coming years — 3 to 10 — there will undoubtedly be some spectacular failures, as there always are when new, challenging fields of human endeavor are attempted for the first time. If the history of similar private-sector initiatives is a good indicator for this case — and we believe it is — then it is quite likely that there will also be a few spectacular successes, and that these will change the course of deep-space exploration and utilization forever.

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References

[1] The recent discovery rate of NEAs (with three active search programs in place) is about 8 to 10 per month. In mid-1990, there were around 150 verified, cataloged NEAs; now there are over 450. (These figures based on remarks made by Elanor Helin at an evening JPL lecture on 1998 Feb. 19.)

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[14] 1991, Fjermedal, G.: *Sail of the Century*; Final Frontier, National Space Society.
[15] This effort was derived from a 1984-85 study JPLer Jim French conducted for SSI.
[16] 1990 Oct. 18: Newswire release; UPI, (The team was assisted by a small startup firm in California, Omni Systems, Inc., which evolved to be Spectrum Astro, Inc.)
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