Space Exploration Advocacy in the 21st Century:

The Case for Participatory Science

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Abstract

Space exploration advocates and science communicators have long lamented a perceived lack of public understanding of science, linking it to low public support for space exploration and scientific research activities. This paper challenges the notion that the average citizen is not interested and does not understand science; indeed, it will argue that he/she is very interested, but under the current system, has little or no way to participate – particularly in space exploration – in a *real* and *meaningful* manner. The author will also argue that "participatory science," defined here for the first time, may be the key to increasing space and scientific literacy, increasing support for some and also expanding the amount and scope of research that can be conducted.

Introduction – Why We Need Participatory Science

> *The public is not hostile to science. Rather, busy with other concerns, it entrusts the care and feeding of science to others, even if unsure about who they are and what they are doing.*
>
> -- Daniel Greenberg

The Problem with Space Exploration

It has now been more than forty years since the Soviet Union (USSR) launched *Sputnik* into space and more than thirty years since the United States (US) put a man on the Moon. We have not returned to the lunar surface since the *Apollo* program ended, nor have we flown any men or women beyond the Moon. Although we have learned how to exploit low Earth orbit (LEO) in the meantime, and learned much from deep space probes, the public seems both frustrated and disappointed. Those who support space exploration want to know why we are not doing more; those who are actively against space exploration do not understand why continued space exploration is important.

While interest in the US space program was quite high in the years leading up to the Moon landing, the public has been quite fickle ever since, tuning in *en masse* only when there is a major problem (*Apollo 13* or *Columbia*) or a significant triumph (the successful *Pathfinder* mission on Mars).

A poll conducted in 2002 showed that when asked which federal program should be cut first to fight budget deficits, 37 percent of those polled chose the space program. Using previous Gallup polls for comparison, support for more dollars for the space program hit its lowest ebb last year since 1993. Even worse, more than half of the respondents opposed a manned mission to Mars, and 11 percent agreed with a statement that said that NASA no longer had a purpose and should be disbanded (Shaw 2002).

In 2001, according to *Science and Engineering Indicators 2002*, 48 percent of those Americans surveyed thought spending on space exploration was excessive, the highest percentage for any item in the survey. Approximately 45 percent of the public agreed that the benefits of space exploration outweigh the costs, down from 49 percent in 1999. Not since 1985 (before the *Challenger* accident) have more than 50 percent of respondents to NSF's public attitudes survey stated that the benefits of the space program exceed the costs. The authors of the report say "survey data suggest that most of the public is having difficulty recognizing the benefits of the space program" (NSB 2002).

In a more recent poll, when presented with no other option, three-quarters of Americans would maintain or increase funding of NASA, but when given a choice, Americans say they would rather direct more government money to health care and national defence than to continue funding the space program (Gallup 2003). Meanwhile, *Popular Science* magazine has recently characterized NASA as having lost its focus and being caught in a "mid-life crisis" with no real purpose to guide it (Stover 2002).

The Problem with the Space Problem

Why is support for space exploration seemingly so capricious? space advocates lament. How can we return to those halcyon days of the *Mercury*/*Apollo* era when everyone was pro-space and when astronauts were celebrated as heroes?

Apart from the fact that there has never been 100 percent support for space exploration (there were critics of the space program even at the height of the panic over being beaten by the Soviets (Burrows 1998, 332)), historians now agree that the circumstances that led to the space race were exceptional.

For one thing, the historical, ideological, and social factors that led to the Cold War are not likely to be repeated. Although some space advocates are hoping for a repeat space race between the US and China, this is unlikely; the space age is already more than 30 years old, and most of the major "firsts" (first man, first woman, first multi-man mission, etc.) have already been achieved. Culturally speaking, China is not a country inclined to race anyway, preferring instead a patient, steady, incremental approach. Given their slow but persistent changes in foreign policy, designed to gain more acceptance from world players (e.g., the successful bid for the 2008 Olympics), it is possible that China may seek a cooperative approach rather than a competitive one for larger, more expensive missions like a foray to Mars.

There are also too many other issues competing for public policy attention in the 21st century for space to take centre stage any longer, particularly in the US. The inspirational speeches that Kennedy made to Rice University and to Congress in the early 1960s worked only because the US public and its Congressional representatives had been surprised by the USSR's apparent successes, and the pump had been primed, so to speak, when Eisenhower's restrained approach contrasted sharply against clever "missile gap" campaigning by Kennedy and Johnson prior to their taking office. "Recapturing that magical moment has been the implicit goal of NASA until only recently," argue the authors of *The Myth of Presidential Attention to Space Policy*; "[however,] space programs must become not only economically viable, but also *linked with the general* *public in meaningful ways*" (Handberg, Johnson-Freese, and Moore 1995; emphasis added).

Another significant issue is that a tremendous gap has opened up between public expectations and the reality of space exploration. This gap exists for two reasons: First, in order to convince the public that a Moon landing was indeed possible,[1] authorities – most notably Wernher von Braun – went to great lengths to educate the US public[2] about the technology and possibilities it offered. The descriptions included fantastic Moon colonies, space stations, and manned missions to Mars. Artists, movie makers, and authors also contributed to this futurescape, in some cases with wildly speculative visions of the upcoming century. Second, NASA faltered after *Apollo 11*, sending its crews back to the Moon several times without demonstrating that doing so was laying groundwork for the promised lunar colonies. The US public breathed a sigh of relief at having beaten the Russians and tuned into the Vietnam War and other areas of civil strife. According to Howard McCurdy:

> The reality of space travel has depleted much of the vision that originally inspired it. Space-flight engineers have not developed technologies capable of achieving the dream; advocates have not formulated alternative visions capable of maintaining it… The dreams continue, while the gap between expectations and reality remains unresolved. (McCurdy 1997)

[1] In spite of *Sputnik*, many were sceptical about space travel and particularly a Moon landing, thinking, for example, that the Moon was clearly only the size of a basketball and thus landing on it was a ridiculous proposition.

[2] And, by extension, the international public, at least where a free press was available and the editors deemed the space race newsworthy.

More than 30 years later, NASA is still seen by some to be stumbling. It appears to have no clear purpose and has either morphed into a bloated, unresponsive bureaucracy or has attempted to be all things to all players (while pleasing no one), depending on whom you talk to. Therefore, another part of the problem is that NASA does not appear to know who its customers really are or how to meet their expectations (Mandell 2000). To be fair, it is a complex question. Are the customers the people who pay the bills, that is to say, the taxpayers? If so, do they expect another *Apollo* spectacle, or are they happy with a steady program of discovery that mixes both human and robotic elements? Or are the customers the companies and organizations who actually use the launch and research and development facilities? Other agencies, such as the European Space Agency or the Indian Space Agency, seem to have a clearer view of their mandate; this may be because they are younger agencies, unencumbered by the tyranny of a past space spectacular.

Finally, there is the persistent, problematic use of the frontier metaphor when discussing space exploration. Most likely originating in the US because of the Wild West myths and legends in popular histories of America, it has been taken up by space advocates around the globe. The metaphor is now politically loaded; the romantic pictures of the first pilgrims coming to a rich and bountiful land to enjoy freedom have been replaced by visions of conquerors that displaced indigenous peoples and wreaked environmental havoc (Billings 1997). The word "frontier" also no longer really applies anyway, since access to low Earth orbit, at least, has been made routine by dozens of shuttle and satellite launches.

More significantly, however, the word "frontier," when applied to space exploration, can never truly have struck a chord with the public at large. *This is because* *the average citizen has never been able to participate.* In nearly all previous frontiers or exploration efforts, the average citizen could – and did – participate. In some cases, only those who were independently wealthy or who had enough salesmanship to secure patrons and sponsors could mount expeditions for the sake of exploration, but even the poorest of the poor could eventually scrape together enough to attempt an Atlantic passage to become settlers and pioneers in the new worlds.[3] To date, space exploration has been the exclusive preserve of only a few dozen astronauts financed by only a few nations around the world.

The Space Community's Response

The space exploration advocacy community has valiantly tried to capture and focus the public's attention on space issues. To its credit, it has actively tried to involve the average citizen; unfortunately, the methods chosen no longer seem to be very effective, and they also result in a divide between scientists and non-scientists.

After realizing that the US space program was losing its way in the late 1970s, space enthusiasts decided to try to build grassroots advocacy societies. The main idea was that ordinary citizens could be organized to take political action (write their government representative, hold rallies, etc.) and pay membership dues to finance projects (mostly public awareness campaigns or for political lobbying purposes, but more recently for actual space-related research). There are several of these societies, some with planet-specific agendas (Mars Society 2003), others with space exploration overall as their

[3] Some were even forced into a frontier, like the criminals, usually debtors, who were shipped to penal colonies in Australia.

target (Planetary Society 2003), and others with specific ideological or political strategies (Space Frontier Foundation 2003).

There are at least two fundamental problems with this approach. First, space advocacy societies must compete for the public's attention with literally hundreds of other activist groups. The Mars Society's message of "The time has come for humanity to journey to Mars" must fight for attention over other serious (and perhaps more immediately pertinent) messages like "Let's Make Cancer History" (Canadian Cancer Society 2003) and even not-so-serious (but also, perhaps, more immediately appealing) messages like "July is Blueberry Month in the USA!" (Blueberries 2003).

More fundamentally, however, these grassroots societies provide very little for the average member to actually *do*. Unless a member happens to also be a space scientist who has the skills to contribute to the design and implementation of research projects or policy papers, the average member is usually only called upon to a) donate money, b) read the society newsletter, c) donate more money, and d) occasionally sign a petition or draft a letter to his/her local government representative. If the member is fortunate enough to live near a society chapter, he/she can go to meetings to watch presentations or learn how to do presentations to outside groups to "spread the word." This evangelical approach involves both educating the public to increase their science and space exploration literacy levels and trying to explain why space is important.

"One of the most egregious failures of space advocacy," writes John Carter McKnight, "has been to put to good, sustainable use the skills and energies of the people its polemics have inspired… Congressional letter writing, street corner leafleting and neighbourhood stamp-club style meetings have long outlived their day." (2003)

In the attempts to increase science literacy in general and to increase support for space exploration specifically, the communities involved have tried but mostly failed to address the problems. A significant gap still remains between the rocket scientists and the lay public, and it may be that the gap is widening. Participatory science, defined in the next section, may be a way to bridge that gap and bring the two sides together.

Chapter 1 – Participatory Science Defined

The effort to understand the universe is one of the very few things that lifts human life a little above the level of farce, and gives it some of the grace of tragedy.

-- Steven Weinberg

A Few Other Scientist–Non-Scientist Interactions

Recently, journals for many different disciplines have published articles referring to participatory studies or terms like "civic science" to describe varying types of scientist to non-scientist interactions. Before we get into what participatory science *is*, we shall quickly review these other terms in order to demonstrate what it *is not*.

Participatory research tends to refer to research done on *and* by, or with, non-scientists or done in the area in which non-scientists live (Cornwall and Jewkes 1995). An example would be a study of an area where the water is thought to be polluted; the local residents could press for a study, provide a history of perceived problems to researchers, volunteer themselves to be tested for various problems, and collect data in the form of water samples and so on. This is different from a typical clinical study where subjects provide informed consent to a procedure or a drug, but usually have little or no say in the design or implementation of the study. As the term implies, participatory research allows for some non-scientist input into the analysis being done on or around them; the level of participation varies from study to study.

The terms *civic scientist* and *civic science* have been used to describe two different models of public outreach. In one model, civic science is where a scientist engages the public by actively seeking ways to talk about science – for example, doing presentations at a local service club or being the guest on a radio show. In another model, *civic science* is a process of linking both experts and stakeholders in some sort of planning activity, such as environmental improvement. *Citizen scientist* and *citizen science* are terms that have been used to describe several concepts. They have been used to discuss science that assists the needs and concerns of citizens and to denote a form of science developed and enacted by citizens themselves. Another use is to describe a citizen (non-scientist) who attempts to evaluate scientific arguments in the context of social issues. *Citizen activist* is used to characterize projects that are initiated by members of the public rather than scientists – the terms *people's science* and *popular science* have also been used to describe this phenomenon. A *scientist-activist*, meanwhile, refers to scientists who see and deliberately use science as a tool to improve people's lives in the physical sense as well as in social and cultural contexts (Clark and Illman 2001).

What *is* Participatory Science?

While the above-listed interactions are commendable, they generally only involve meeting a limited number of outreach or educational objectives. They may also maintain or even increase the gap between scientists and non-scientists because of the preconceptions on which they are built.

The concept of *participatory science* is designed to meet a broader range of scientific, educational, and outreach objectives, and to bridge the gap between the two groups. It is also designed to do so without lowering standards (which can result in patronizing non-scientists) or reducing the esteem to which professionals should be regarded (which could lead to resistance to the concept).

To be deemed participatory science, a project or program *must* have the following characteristics:

It must involve both scientists[4] *and non-scientists working together, preferably in real time or near real time*. This is perhaps the most obvious part of the definition, but one that is important nonetheless.

Non-scientists must not *be the subject of the research*. If the non-scientist is the subject of the research, this automatically creates a large power imbalance between the two groups, especially if the research is medical in nature. (See "Tipping toward equal" below.)

The primary purpose of the project or program must be original research and/or development. *Further, a participatory science project or program must involve one or more of the following: observation, data collection, data aggregation, data processing, theory/model construction, analysis and interpretation, or development*. For most scientist–non-scientist interactions, the primary goal is usually education and outreach. Any science that is done has usually been done before; the outcome is known by the scientist and is being recreated for demonstration purposes. In participatory science, the primary goal must be the creation of something new – new data, new analysis, a new proof (or disproof) of a hypothesis, etc.

[4] For the purposes of this discussion, a "scientist" is defined as someone who most likely has one or more advanced degrees and whose primary source of income is derived from a job or post that involves scientific inquiry as its main activity.

Non-scientists must contribute to or participate in the science *of the project or program in a* real *and* non-trivial *manner.* Too often, interactions between the respective communities involve “token” participation. Examples of this would include *Project Starshine*, where students polished sections of satellite casing to make it highly reflective, going on to observe and track the satellite after it was launched (Maley, Moore, and King 2002); and *Deep Impact*, where members of the public are invited to “send their names to a comet” (NASA). While this may be sufficient for interactions with young children (and to be fair, that was the intended audience for *Starshine*), older participants want more than this sort of vicarious association.

Participatory science must be geared toward adults. Although bright and interested children should never be prohibited from taking part in a project or program, these endeavours should be designed primarily for adults. This is because there are plenty of initiatives already in place to reach children (see Chapter 3 discussion). Further, the materials used in participatory science projects should assume that the participants want to learn and want to be challenged – not to be “talked down to.” It is the adult population, after all, that is currently called upon to make decisions about matters of public policy. Parental attitudes and levels of knowledge also have profound effects on their children. The fundamental assumption here is that we want to *raise* scientific literacy, not lower the standards of discourse between scientists and non-scientists.

Participants must be given the opportunity to learn. Participants should not simply be assigned tasks without being given any context, history, or rationale. Part of being scientifically literate includes understanding the scientific process. School curricula are notorious for this – students are regularly taught calculus with very little explanation as to what it is used for in the real world and why it might be important. At best, math class becomes an exercise in enduring endless computations that have no value apart from what shows up on your test score; at worst, the endless calculations are confusing, meaningless, and for some, even frightening. Participatory science projects must provide users with the “bigger picture.”

To be deemed participatory science, a project or program *should also* have the following characteristics:

It should allow for either passive or active participation, especially active, but preferably both. Interested members of the public might have limited time and resources to devote to a particular project or program, even if they are keenly interested. These people should be given the option of being able to participate even if only in a passive way (e.g., downloading a software client to their personal computer that works in the background or as a screen saver.) That should not be the *only* mode of participation, however, because in order to learn, in order to feel part of the research community, a participant should be *doing* something.

It should provide public outreach as its secondary objective. In addition to conducting a scientific investigation, a participatory science project should be visible. That is, it should maintain a project website to attract new participants and inform casual surfers and media about its activities and issue press releases when relevant milestones are reached or something new has happened. Participants (both scientists and non-scientists) should be available for speaking engagements and presentations.

Participatory science projects should be used in any discipline and in either pure or applied research questions. To provide as much variety and scope as professional scientists regularly access, participatory science projects should be done in any discipline where practitioners have enough creativity to create one. Projects should deal with the esoteric (e.g., searching for Mersenne prime numbers) and/or the practical (e.g., robotic design).

Organizers should allow participants to contribute to facilitation of the project. Different people have different skills and strengths. A potential participant in an astronomy program may not have good celestial observation skills but have excellent programming skills, which could be put to use, for example, in writing image processing software. Whenever it is feasible to expand the scope of non-scientist input, it should be considered.

Tipping toward equal. Speaking in sociological terms, participatory science should allow the balance of power in the relationship between non-scientists and scientists to move toward equality. In the past, the scientific community has been accused of setting itself up as the new high priesthood, holding itself above a lay public, making pronouncements about what is right and what is wrong. While it is certainly right to distinguish between those who do science for a living and those who only do it part-time, it is also important to remember that the word *amateur* originates from *to love.* Amateurs do what they do, often without compensation, strictly for the love of the subject. They should be taken seriously and afforded relationships in these projects anywhere along the continuum suggested by Biggs: contractual>consultative>collaborative>collegiate (qtd. in Cornwall and Jewkes 1995).

A participatory science endeavour should include some mechanism for publicly recognizing and rewarding non-scientists in the same way that scientists have *recognition systems set up by and for their peers*. Obviously, if some 10,000 people participate in a project, it is not practical to list everyone's name on the resulting journal papers. However, contributors can have their names posted on the project website or perhaps listed in an advertisement announcing the successful end of the project. High achievers can be rewarded with special titles or positions within the project hierarchy; significant contributors to one or more projects could be recognized at an awards night. Whatever the mechanism, non-scientist participants should be made to feel that their contribution was valued, and further, that they were not just used as free or cheap labour.

The Earthwatch Example

One of the first organizations in the field of scientist–non-scientist interactions was the *Earthwatch Institute*. The institute publishes a bimonthly magazine that details research projects taking place around the world; each project is described and marketed much like a holiday package. Interested members of the public can select an "expedition" based on their interests, the region they would like to visit, or what time they have available.

For example, in November 2003, Earthwatch sponsored a project to study the behaviour of male polar bears in Churchill, Manitoba. Volunteers who wished to take part *paid* $3,660 (US), which covered their participation as well as their contribution to the project funding overall, and had to arrange for their own travel; participants stayed for about a week in shared accommodations in a field station, at a time of year when it is typically about -20 to -30ºC in Manitoba (Waterman 2003).

The costs and conditions for this and other expeditions are certainly rather daunting. In effect, non-scientists are paying for the right to do free labour in adverse conditions; further, Earthwatch does not appear to have a mechanism for publicly recognising its volunteers.[5]

Obviously, this is not an ideal example of a participatory science project in terms of what is expected of versus what is returned to the non-scientist population; the model could use considerable improvement in terms of making the experience more equitable. However, it is an excellent example of a mechanism for allowing non-scientists to do real and meaningful work, as well as a way for scientists to be able to collect larger amounts of field data than might otherwise be possible.

In the next chapter, some space exploration participatory science projects are catalogued.

[5] There is currently no list of past or present volunteers on the Earthwatch website, and the site's Frequently Asked Questions (FAQ) page makes no mention of whether or not volunteers are credited for their work in any way. Some mention may be made of member names in the institute's communications, but this would constitute internal recognition only.

Chapter 2 – Space-Related Participatory Science and Projects That Could Be Adapted

> *Science is nothing but trained and organized common sense, differing from the latter only as a veteran may differ from a raw recruit: and its methods differ from those of common sense only as far as the guardsman's cut and thrust differ from the manner in which a savage wields his club.*
>
> -- Thomas H. Huxley

While certain fields of study have begun to initiate more participatory science projects, the concept is not yet well known, properly defined, or widespread. There are a respectable number of medical and environmental projects currently ongoing, but space-related projects are thin on the ground (and in the skies). Catalogued here are past, present, and future projects, as well as some "not-quite participatory science" endeavours that could be tweaked to fit the definition and accomplish real science.

Project Name:	**Analytical Spectroscopy Research Group and the Search for Extraterrestrial Intelligence**
Purpose:	To search for artificial intelligence using microwave telescopes.
How It Works:	Volunteers download a sound file (recorded using a microwave telescope) from their server, import it into a program that displays sound in graphical form (i.e., a waveform), and visually inspect it for unusual signals. There is also a processing program called SETIEasy for automated searching.
Dates:	Ongoing
Number of Users:	A handful of graduate students.
Accomplishments:	n/a
Special Notes:	n/a
	(ASRG 2003)

Project Name:	**Astropulse**
Purpose:	To analyze radio telescope signals looking for black hole evaporation and other phenomena.
How It Works:	Users download a software program that downloads and analyzes data packets.
Dates:	2003–currently in beta testing mode.
Number of Users:	711
Accomplishments:	793,644 results analyzed and returned.
Special Notes:	This particular project uses BOINC (Berkeley Open Infrastructure for Network Computing), a new, open source distributed computing platform. This means that a) participants can help develop and refine the software; b) users will be able to download one client and register for multiple projects, so when one project ends, their computer switches to another task. (Astropulse 2003; BOINC 2003)

Project Name:	**Auger Project**
Purpose:	To simulate "air showers," phenomena caused by cosmic rays entering Earth's atmosphere.
How It Works:	Participants download the XtremWeb client that downloads and analyzes data packets.
Dates:	Pending
Number of Users:	n/a
Accomplishments:	n/a
Special Notes:	This appears to be either in the proposal or beta stage. (XtremWeb 2003)

Project Name:	**Centre for Backyard Astrophysics**
Purpose:	Photometry of cataclysmic variables.
How It Works:	Participants are asked to focus their observations on particularly interesting targets and report observations.
Dates:	1991–present
Number of Users:	26 observing stations around the globe.
Accomplishments:	Data collected so far has resulted in 27 papers in refereed journals.
Special Notes:	n/a (Center for Backyard Astrophysics 2003; Ferris 2002)

Project Name:	**Clickworkers**
Purpose:	To identify and classify craters on Mars, to determine if Pathfinder magnets collected magnetic dust on Mars, to search for "honeycomb" terrain on Mars.
How It Works:	Users visited the project website, viewed real images collected from various Mars probes and identified craters by clicking in a circular pattern, choosing which of two images has more dust in a pattern and searching pictures for honeycomb landforms.
Dates:	November 2000–September 2001
Number of Users:	800+
Accomplishments:	An age map of Mars was created using Clickworker input, which fairly closely agrees with expert consensus. Project authors found that Clickworkers, on average, could produce reasonably reliable data; improvements could be made to site instructions and program algorithms for crosschecking and redundancy.
Special Notes:	This was a pilot project for proof of concept and not widely advertised. (Clickworkers 2001; Kanefsky, Barlow, and Gulick 2001)

Project Name:	**ClimatePrediction**
Purpose:	A project to predict Earth's climate 50 years from now. Not strictly space exploration related, but data input comes from observation satellites; results may have a bearing on what we launch for future observations.
How It Works:	Participants download a small program to their computer; it uses spare Central Processing Unit (CPU) cycles to run a simulation.
Dates:	2003–present
Number of Users:	41,061
Accomplishments:	564,557 model years simulated already; 5,170 full runs and 32,333 short runs completed.
Special Notes:	Has a user community page at the website; Open University plans to offer a course about climate prediction; users get to see their stats and compete for rank against other users. (ClimatePrediction 2003)

Project Name:	**Citizen Explorer Satellite**
Purpose:	To measure ultraviolet (UV) radiation and ozone to develop understanding as to how they affect us.
How It Works:	Schools will become ground stations. Students will perform measurements of UV radiation and aerosol particulates in the air using handheld instruments called a UV-B detector and an aerosol meter. This data will be used in the calculation of ozone levels in their areas. These calculations will then be compared with the ozone data sets produced by the satellite instruments. The satellite itself is to be designed by undergraduate and graduate students.
Dates:	The first satellite, CX-1, is awaiting a launch date.
Number of Users:	n/a
Accomplishments:	Pending
Special Notes:	Technically, this does not qualify as a participatory science project under the definition given in this paper: the primary purpose appears to be outreach and it is primarily aimed at school-aged children. However, it is included here as an example of a space project that could easily be adapted to be a truly participatory science endeavour. (Citizen Explorer Satellite 2003)

Project Name:	**The Edgar Wilson Award**
Purpose:	Establish recognition of amateur contributions to comet discovery.
How It Works:	Up to $20,000 USD is awarded to amateur astronomers who have been confirmed as discovering a new comet within the award year period.
Dates:	1998–present
Number of Users:	All amateur observers are eligible. Reporting procedures must be followed and the discovery must be confirmed.
Accomplishments:	n/a
Special Notes:	Not a participatory science project at this time because it is not a coordinated effort between professionals and amateurs. However, it is significant recognition of non-scientist contributions by the scientific establishment. (Edgar Wilson Award 2003)

Project Name:	**Globe**
Purpose:	Students performing hands-on science.
How It Works:	While completing their science courses, students do real field work in environmental and ecological sciences, taking measurements using instruments provided by the program and logging them into an Internet database. Professional scientists have found the data useful, particularly for providing ground truths for remote sensing applications.
Dates:	The program has been running for approximately six years.
Number of Users:	12,000 schools and 20,000 trained teachers.
Accomplishments:	The program recently logged 10 million measurements.
Special Notes:	Not a participatory science program because the goal of the program is primarily education and outreach, and it is aimed at school-aged children. However, given that it involves an immense, already established global network of participants, scientists could quite easily set up participatory science projects that require real data collection and analysis to be completed through this program. (Globe 2003)

Project Name:	**Expedition One**
Purpose:	Mars-analogue rover, datalogger, and suit technology testing; group processes and task analyses studies to optimize field work for an intensive geology and biology research program at a Mars analogue site.
How It Works:	Members of this project set up a simulated mission to Mars at an analogue station in Utah (the Mars Desert Research Station) at a site selected because of its basic similarities to Mars. Field crew members lived in the station as though it were a Mars habitat; conducted extravehicular activities (EVAs) to do research on the geology and biology of the area; tested design issues with simulated rovers, suits, and datalogger equipment. Mission control and support was located in Toronto, Ontario.
Dates:	February 15, 2003–March 16, 2003
Number of Users:	The members of Mars Society Canada and Mars Society Australia.
Accomplishments:	Nine published papers to date; planning for Expedition Two, which will take place at an Australian site, is underway.
Special Notes:	In addition to biologists and geologists, this project made optimal use of Mars Society's membership. Non-scientist members contributed to public relations, video, and electronic documentation of the mission, IT support, fundraising, project management, engineering, and human factors. (Persaud et al. 2003)

Project Name:	**Informal arrangements**
Purpose:	n/a
How It Works:	Professional scientists at large observatories like the Solar and Heliospheric Observatory (SOHO) post images collected from the instruments on the observatory website – quite often before they have had a chance to analyze the data themselves. Anyone with an Internet connection and some image processing software can download and examine them. Amateurs are making their own discoveries this way. For example, Michael Oates has discovered more than 100 comets, and some high school students found one of the first Kuiper Belt Objects.
Dates:	Since observatories began posting images on the Internet to present day.
Number of Users:	Unknown
Accomplishments:	Total amateur contribution using this methodology has not been documented, but there have been at least 100 comets, several variable stars with complex pulsation cycles, and Kuiper Belt objects identified already.
Special Notes:	Not a formal participatory science project in the sense that this was deliberately set up for interaction, but provides excellent proof that amateurs are not only willing but quite able to do good scientific work. Given the sheer volume of astronomical data modern day observatories are collecting and the usual problems with funding and staffing, more effort should be made to recruit and definitely recognize non-scientists for analysis. (Sincell 2001)

Project Name:	**The International Space Station Amateur Telescope (ISS-AT)**
Purpose:	To allow amateur astronomers access to their own space-based telescope.
How It Works:	The telescope will be delivered to the Space Station on an ISS EXPRESS (EXpedite the PRocessing of Experiments to Space Station) pallet and mounted on the ISS truss. The telescope optics will consist of a Cassegrain telescope with an aperture between 350 and 400 millimetres and a focal length commensurate with diffraction-limited imaging of celestial objects. An array of CCD detectors (charge-coupled devices) will capture images for transmission to Earth. The ISS-AT observing program will consist of a broad-based program of synoptic planetary observations, selected deep-sky objects, and observations proposed and requested. Observations will be placed on an ISS-AT Internet site within 24 hours of receipt, and all data will be placed in the public domain. A prototype ground-based telescope, the Alpha Telescope, is already operational.
Dates:	The current goal for operation is 2006.
Number of Users:	All amateur astronomers.
Accomplishments:	Excellent deep-sky imagery already available on the site.
Special Notes:	Volunteers encouraged to help with getting ISS-AT off the ground. (ISS-AT 2003)

Project Name:	**The Innovative Technologies from Science Fiction for Space Applications (ITSF)**
Purpose:	A study on technologies and concepts found in science fiction in order to obtain imaginative and innovative ideas potentially viable for long-term development by the European space sector.
How It Works:	Users join the ITSF E-mail Discussion Forum and/or fill in the Fact Sheet Submission Form.
Dates:	2000
Number of Users:	n/a
Accomplishments:	50 fact sheets and 35 technical dossiers covering some 250 concepts and technologies were generated as a result of the first phase of the study.
Special Notes:	n/a (ITSF 2000)

Project Name:	**LifeMapper**
Purpose:	Lifemapper computes, maps, and provides knowledge of where Earth's species of plants and animals live; where Earth's species of plants and animals could potentially live; and where and how Earth's species of plants and animals could spread across different regions of the world. Data is coordinated with remote sensing and Geographic Information Systems (GIS) systems for the study of environmental issues, land planning, and epidemiology.
How It Works:	User downloads a screensaver that retrieves records of millions of plants and animals in the world's natural history museums. Lifemapper analyzes the data, computes the ecological profile of each species, maps where the species has been found, and predicts where each species could potentially live.
Dates:	November 1, 2002–present
Number of Users:	2,815
Accomplishments:	Approximately one-third of the species under consideration have been georeferenced so far. (LifeMapper 2003)

Project Name:	**LunaCorp Telepresence**
Purpose:	To allow members of the public to steer a lunar rover around on the Moon.
How It Works:	Users with highest scores in simulations will get a chance to drive a rover around.
Dates:	Pending
Number of Users:	n/a
Accomplishments:	n/a
Special Notes:	At this point, the LunaCorp project is not science based. It is strictly for public outreach, and the slant is highly commercial. However, if successful in commercial terms, it is possible that rovers might be made available for amateur studies of the Moon. (LunaCorp 2003)

Project Name:	**Optical SETI**
Purpose:	To search for extraterrestrial intelligence using optical telescopes.
How It Works:	Users will add a sensitive laser detector to their optical telescope, software to their PC, and locate themselves exactly using the Global Positioning System (GPS).
Dates:	Proposed in 2000.
Number of Users:	n/a
Accomplishments:	n/a
Special Notes:	This appears to be in the proposal stages only. (OpticalSETI 2003)

Project Name:	**The Prairie Meteorite Search**
Purpose:	To find meteorite specimens in the Canadian prairies.
How It Works:	A graduate student from the project canvasses towns, schools, etc., showing examples of meteorites and giving lessons on how to spot and report them.
Dates:	2000–present
Number of Users:	All residents of the Canadian prairies.
Accomplishments:	In limited field seasons and with minimal publicity, area residents have recovered and turned in five new specimens.
Special Notes:	n/a (Hildebrand 2003)

Project Name:	**Project Argus**
Purpose:	To search for artificial intelligence using a network of amateur microwave telescopes.
How It Works:	Argus is an effort to deploy and coordinate roughly 5,000 small radio telescopes around the world in an all-sky survey for microwave signals of possible intelligent, extra-terrestrial origin.
Dates:	April 21, 1996–present
Number of Users:	121
Accomplishments:	At the end of 2002, 119 Project Argus radio telescopes in 22 countries, built and operated by volunteers, logged in more than 100,000 hours of astrophysical observations.
Special Notes:	A Project Argus can be built for a few hundred up to a few thousand dollars; the SETILeague provides plans. (SETILeague 2003)

Project Name:	**Robocup**
Purpose:	By the year 2050, develop a team of fully autonomous humanoid robots that can win against the human world soccer champion team.
How It Works:	Participants sign up and design a team of robots that can play football (soccer) against another team.
Dates:	1993–present
Number of Users:	First competition in 1997 featured 40 teams, 5,000 spectators, and coverage by 70 world media organizations; RoboCup 2004 will be in Portugal and features RoboRescue and RoboCup, Jr.
Accomplishments:	Has become the Olympics of robotic competition; dozens of papers published on the subject. Collaborative effort has led to numerous incremental improvements in robotic design and control.
Special Notes:	Robotic missions are vital to long distance space exploration in the near future; developments that allow a robot to play football will certainly allow it to explore rough terrain and even work as a member of an expedition team. (Asada and Kitano1999; RoboCup 2003)

Project Name:	**Seti@Home**
Purpose:	A scientific experiment that uses Internet-connected computers in the Search for Extraterrestrial Intelligence (SETI).
How It Works:	Radio SETI telescopes listen for artificial radio signals coming from other stars. The Seti@Home project breaks the recorded data up into small packets that need to be analyzed for unusual signals. Anyone with a computer and an Internet connection can perform this analysis by downloading a small software program and installing it. The program automatically connects to the Seti@Home server, downloads a data packet, and performs the analysis using the spare processing power of the user's computer. When the analysis is complete, the program sends the data back to the server and collects another packet.
Dates:	1998–present
Number of Users:	4,740,324
Accomplishments:	1,103,041,740 packets analyzed; 1,279,453 years' worth of CPU time donated; 56% of the visible sky scanned three times; only 5.2% of the visible sky has not been scanned once; 2,568 "persistent Gaussians" or potentially interesting signals found to date.
Special Notes:	The website lets users submit profiles and pictures of themselves and has an online poll with questions concerning demographics, SETI, and distributed computing. Users have created various ancillary software, such as proxy data servers and systems for graphically displaying work progress. Users have translated the website into 30 languages. (SETI 2003; Anderson et al. 2002)

Project Name:	**Spaceguard Detective Agency**
Purpose:	To detect asteroids using image comparison software.
How It Works:	Participants were given a software package and a series of images to compare.
Dates:	2002
Number of Users:	n/a
Accomplishments:	n/a
Special Notes:	This was a pilot program developed by the Japanese Spaceguard group. It was designed to both detect asteroids for discovery and collision identification purposes and to teach users about solar system mechanics. (Isobe et al. 2002)

Project Name:	**TransitSearch**
Purpose:	A cooperative observational effort that will allow experienced amateur astronomers and small college observatories to discover transiting extrasolar planets.
How It Works:	Amateurs with the right equipment (specific types of lens and some software tools as shown on the project site) will be assigned observational candidates and will be asked to report their results.
Dates:	In beta; observational methods being tested with a limited number of target candidates and astronomers.
Number of Users:	n/a
Accomplishments:	n/a
Special Notes:	Tim Castellano of NASA's Ames and Greg Laughlin of the University of California, Santa Cruz, set up this program after they learned that a Finnish amateur astronomer had charted the path of a planet across the star HD 209458. (TransitSearch 2003)

Project Name:	**XPulsar@Home**
Purpose:	Model the spreading of x-ray photons in x-ray pulsars.
How It Works:	Users downloaded and ran an applet that ran a simulation.
Dates:	March 12, 2001–March 12, 2002
Number of Users:	8,432
Accomplishments:	1.2 million CPU hours
Special Notes:	n/a (UniversitätTübingen 2003)

Chapter 3 – Why Participatory Science Will Work

Public support for space exploration is lukewarm 40 years after Gagarin's flight because the people paying the bills are still relegated to the role of passive observer.

-- The lead editorial in *Space News*, April 9, 2001

Participatory science may be the key to educating the public about space exploration, involving them, and therefore increasing support for space exploration efforts overall. However, some questions remain. How literate is the public to begin with? Are they capable of participating? Why is there such a gap between scientists and non-scientists in the first place? Is the general public really interested in participating? And finally, will scientists be willing to set up participatory science projects?

The Scientific Literacy Issue

Since 1972, the National Science Foundation (NSF) in the United States (US) has produced biennial reports designed to provide quantitative information about the state of American science, engineering, and technology. Advocates and communicators have been particularly interested in statistics relating to the general public's science literacy.

The results of the surveys are not especially encouraging. The authors of the report characterize US science literacy as being "fairly low." For example, just 70 percent of respondents knew that plants produce oxygen and that light travels faster than sound, and only half of the respondents knew that humans and dinosaurs did not co-exist or that antibiotics do not kill viruses. Further, only 20 percent of respondents could define the term *molecule*, and especially astonishing in this era of genetic discovery, only 45 percent provided an acceptable definition of *DNA* (NSB 2002).

Trends over time also reveal some dismaying figures. In a look at public belief in astrology since 1971, the current trend for agreement with the statement "It's not at all scientific" is actually down, while agreement for the statements "It's sort of scientific" and "very scientific" is increasing. Further, belief in the paranormal – things such as haunted houses, extrasensory perception, and communication with the dead – went up between 1990 and 2001.

The general public's understanding of the scientific process is also very low. Less than one-third of the respondents, approximately 30 percent, could successfully demonstrate that they understood what it means to study something scientifically. This is of particular concern to some because of the way science is reported in the media; without a clear understanding of how hypotheses are tested and debated, communicators worry that the public will be confused by conflicting statements from scientific authorities about major public policy issues such as global warming or water pollution.

Defining Public Understanding

At first glance, the statistics are disheartening and depressing for anyone concerned about the public's ability to make sound, informed decisions about science-related issues. Clearly, the argument goes: If science literacy is low, public interest in and support for scientific endeavours will also be low; people will also be prone to making the wrong decisions based on incorrect perceptions and information.

As with most issues, the problem is more complex than it seems. First, there is the question of motivation when it comes to measuring the public. Fayard, for example, criticized the burgeoning field of "the public understanding of science"[6] by pointing out that "one of the objectives of some purveyors of scientific popularization seems to be to celebrate and emphasize the difference between those who are in the know and those who aren't" (Fayard 2002). Lewenstein (1992) noted that in the decade following World War II, the term "public understanding of science" became equated with the "public appreciation of the benefits science provides society" (Lewenstein 1992). While a new, more critical approach to science popularization has since gained favour, the scientific community at large still tends to think in appreciative terms.

Science literacy also needs to be considered in context. Taking a sociological approach, Wynne has discovered that there are many complicated factors at play in situations where there is low science literacy (Wynne 1992). For example, in a field study of workers at the Sellafield nuclear fuel reprocessing plant in England, he and his colleagues were dumbfounded to find that employees were not only uninterested in the science of the material they worked around every day, but vigorously defended their ignorance. Wynne discovered that employees had to maintain a wilful ignorance about the potential hazards they had to work around daily, not only for general peace of mind, but also so as not to disturb the social fabric; the workers seemed to feel that by seeking out scientific understanding, they would be signalling that they did not trust the rest of the organization to do its job.

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[6] This field of research has possibly one of the worst acronyms ever, namely, PUS. Martin Rees, who believes the term falsely implies a demarcation between science and the public or "a priesthood and an unwashed populace" suggests GUST – general understanding of science (Rees 2002).

Likewise, he argues that the public uptake of scientific knowledge depends on the trust and credibility of the institutions involved as well as built-up social relationships and identities – a point that will be important later (Wynne 1992). Because of these observations, Wynne believes that current measures of science literacy are somewhat arbitrary, out of context, and not really accurate measures of public understanding so much as they are measures of the diffusion of certain notions (Wynne 1993).

Lévy-Leblond points out that surveys of public knowledge in other fields, such as history, civic affairs, politics, and geography, indicate equally low levels of literacy[7] (Lévy-Leblond 1992). He also stresses that people are not incapable of becoming scientifically literate – it is just that "people show a rather uncanny ability to learn what they need *and not more*: driving without knowledge of mechanics; cooking without knowledge of chemistry; word-processing without knowledge of computer science; etc." Turning the question around, he also suggests that "we rarely think about the symmetrical need for scientists and engineers to acquire the social and political knowledge necessary to let them understand the nature of their own work and ponder the possible effects of their discoveries."

Daniel Greenberg, whose acerbic book *Science, Money and Politics* challenges the notion that the scientific establishment is not getting enough funding or enough support, agrees. He quotes attorney Franklin Raines, who was the head of the Office of Management and Budget in 1998, to point out that the scientific establishment's expectations are part of a double standard:

[7] The authors of the *Science and Engineering Indicators 2002* also acknowledge this fact.

> I daresay, if I went through this audience [of scientists] and quizzed you on the nature of legislating in Washington, D.C., that most of you would come up pretty well short of a fundamental understanding of the process. But I wouldn't blame you for that, because I think you're doing other things… Indeed, the last time I was reading science philosophy, there's not that much agreement within the scientific community about the fundamentals of the scientific process…(Raines qtd. in Greenberg 2001, 232)

Greenberg believes that concern over public ignorance and purported resistance to science is largely a product of self-interest: "Closely related to the hostility alarms is the contention that mass ignorance of science threatens public support of research," he says. "Such ignorance should be corrected, but not for the specious reason that it undermines support of science" (Greenberg 2001, 7).

The Response of the Scientific Community

Given the amount of criticism that has been directed at our methods of measurement and definition of "the public understanding of science," it is quite possible that our approaches to fixing the lack of science literacy in the US and worldwide are likewise flawed.

Much of our response has been focused on children, the idea being to try to instil a lifelong interest in science. In classroom modules, museum exhibits, television programs and websites, the main message seems to be "Science is Fun!" Organizations like the Mad Science group (Mad Science 2003) or the European Space Agency's *Physics on*

Stage (Physics on Stage 2003) have emphasized the flash-bang, gee-whiz aspects of science – things such as indoor fireworks, "burp potions," slimy goo, or the physics of ping pong.

While adult popularizations of science have fared somewhat better, they too tend to take a gee-whiz angle. Television productions like *Hyperspace with Sam Neill* rely on glitzy graphics to animate some of the most far-out theories of astrophysics, while magazines like *Popular Science* print articles like "Why Flying Makes You Feel Like a Rat in a Lab Cage." At best, these things are more entertaining than educational; at worst, the consumer may feel patronized because the material has been "dumbed down."

Meanwhile, any practising scientist who tries to popularize science in a more serious and thoughtful manner can face criticism, ridicule, and jealousy from his/her peers. Carl Sagan, for example, who brought millions of people up to date on theories of the universe in his televised *Cosmos* series and through numerous books and articles, was never elected to the US National Academy of Science in spite of decades of fairly well-regarded work in planetary science. Dan Goldin, a former head of the National Aeronautics Space Administration (NASA), is said to have remarked about the omission: "There was this connotation that if you popularize science, you're not a scientist" (Greenberg 2001, 262; Gwynne 1997).

Another response of the scientific community has been to criticize science media. Journalists have been accused of sensationalizing stories, reporting only half the story, or writing misleading articles and headlines, and not providing enough background information or context. Roger Highfield (2000), the science editor of Britain's *The Daily Telegraph*, tells us that a journalist's job is to *inform*, not to *educate*, and further, that their primary mandate is to find what interests readers, not to tell them what scientists think they should know. Competition in the news business is also fierce:

> Every day, my efforts are judged against three direct competitors and two mid-market tabloids as we fight for the attention of 14 million readers. Every day, my news editor compares my stories, angles, and intros with those in the other nationals. Every day, I have to justify my existence. (Highfield 2000)

Movie and television show producers are lambasted for having faulty science as plot devices. Sometimes the criticism is deserved, such as when health reporters raise false hope by portraying a small step as a "breakthrough cure" for a common disease; in other cases, nitpicking about things like the physics of *Star Trek* (Krauss 1995) obscures the greater service the show has done to encourage people to think about space, science, and international cooperation.

Scientists who have been victims of funding cuts, either as a result of public apathy or fickle politics, through active anti-science campaigns such as the anti-evolutionary theory camp in the US (Holton 1992) or the battle for genetic science in Switzerland (Castelfranchi 2002), have recently begun to fight back in two ways. First, they have engaged the services of public relations firms and professional lobbyists; second, they have formed partnerships and sought funding from private enterprise.

The use of publicity machines was previously considered taboo in the scientific community (Castelfranchi 2002); their use, while understandable in the context of having to fight for a place against many other similarly equipped special interest groups at the government trough, raises questions about the line between fact and truth, spin and hype.

The use of a public affairs office to issue statements on NASA failures and problems, for instance, often leads to additional questions about bureaucratic bungling and cover-up.

Corporate sponsorship and partnership are far more worrisome. A scientist bankrolled by a corporation with a specific agenda risks creeping pro-benefactor bias in his/her research. A scientist who finds cause to lock horns with his/her benefactor, which by default usually has a great deal of money, power, and legal support, risks losing more than just funding. For example, consider the case of Dr. Nancy Oliveri, a medical researcher who had concerns about her sponsor's drug; she ended up unleashing a five year dispute that included court battles, the loss of her job, a poisoned work atmosphere, the loss of several prestigious positions, and a nationwide scandal (Taylor 1998; Livesey 1999). At the very least, whether or not their research is actually compromised by corporate sponsorship, scientists who get their funding this way risk the perception that they are part of a military-industrial-scientific complex. As noted earlier, the public uptake of scientific knowledge depends on the trust and credibility of the institutions involved. Corporate sponsorship can put credibility with the public at risk and widen the gap between the scientific community and the general public.

These and other individual efforts to respond to the public understanding of science seem to have done very little. The 1990 estimate of the level of US scientific literacy showed little improvement over previous studies in 1979, 1985, and 1988. Internationally, about one in 10 adults in 14 countries were deemed scientifically literate (Greenberg 2001, 206). Even coordinated efforts seem to have had no effect: "After well over a decade of efforts to improve what has come to be known as 'scientific literacy' among the general population – led by such organizations as the Committee on Public

Understanding of Science (CoPUS) – surveys suggest that little has been achieved" (Miller 2001).

Thus, scientists looking for support and funding at the beginning of the 21st century are in an untenable position. They basically have the choice of a) picking the pocket of a taxpayer whom they believe do not understand their work, saying, "Trust me, I know best" – a method the taxpayer will no doubt come to resent or b) appeal to private interests and risk being perceived as a corporate shill. Neither choice is likely to do anything but increase an already wide gap between the scientific community and the lay public.

A better solution to both general scientific literacy and the scientific community's need for public[8] versus private support must be found.

Is "Joe Public" Capable?

Science educators and communicators, while reviewing the dismal statistics on the public's literacy, will rightly ask, "If the average Joe can't tell me that the Earth revolves around the Sun, how can we expect him to be able to do *any* science, much less *good* science?"

The question is valid, but it needs to be reframed. The question should be, "If the average Joe can't currently tell me that the Earth revolves around the Sun, but he's given an opportunity to learn-by-doing that it does, can we expect him to do good science?"

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[8] Here, public does not necessarily have to mean direct-from-government funding. It can mean funding from agencies, non-government organizations (NGOs), or personal individual donations. In other words, public can mean anything that is not corporate sponsorship.

The answer is yes. Apart from the anecdotal evidence all around us (people routinely learn complex new software packages or hook up home electronics with little or no formal training, and for the most part, they manage this quite well), studies show that the public is often smarter than we think.

Doble, for example, demonstrated that given a minimal “educational intervention” (in this case, a presentation about global warming and solid waste disposal), the public can make a logically consistent assessment in a short period of time. Indeed, after the presentation, the study group’s views were remarkably consistent with scientists’ views, even though the presentation showed conflicting opinions about the issues (Doble 1995). Miller also reminds us that prior to the days of peer review and professional societies, the latest theories were debated in public and by the public; Pasteur presented his theories in the full glare of media scrutiny (Miller 2001).

Solomon, meanwhile, reminds us that a great deal of public ignorance about science may well be a reflexive defence mechanism and that their responses have a great deal to do with their home traditions. That is to say, in a society where science is culturally deemed to be difficult or even incomprehensible for the layperson, the layperson will likely react with an “I can’t” or “I don’t know” in order to deflect further questions or lessons, which, in this context, only serves to further remind the person they are probably “too stupid” to get it (Solomon 1993).

Demographically speaking, the “baby boomers” are approaching retirement age. This generation is frequently described as the best-educated group yet produced; in addition, societal norms with respect to age have also shifted to such an extent that learning new things later in life is not only accepted but increasingly expected. Thus, it is likely that a majority of “boomers” (and subsequent generations) will want to be intellectually productive after retirement. Astronomy enthusiasts have already found “later life learners” to be a significant and receptive audience (Percy and Krstovic 2001).

There are also vast reserves of potential participants, who, while not practicing scientists, are not exactly laypeople either. Strobel, a physicist who works in engineering, suggests that the “children of Apollo” bought into a social contract that said, “Hey kids, study science, math, and engineering! We’re going to beat the Russians, and you’ll go to the Moon, build space stations, and go to Mars!” but that ultimately turned out to be nothing more than politically expedient rhetoric. “[These people are] trained, ready, and in the prime of their lives, but many have ended up in careers far astray from aerospace. And many that are in aerospace aren’t in positions that permit furthering the cause of space development.” (Strobel 2003)

There is also the argument that the average citizen does not have access to the specialized equipment that is now used to conduct science. While it is true that you cannot find particle accelerators at your local hardware store, the fact is that many instruments can either be purchased as surplus, if the amateur can spare the cash, or built from scratch. Forrest Mims, a renowned non-scientist who spends most of his waking hours conducting science, says:

> When my son Eric wanted to build a novel optical fibre seismometer, a professional seismologist said it would not succeed because our Texas house rests on soil and not bedrock. Eric proceeded anyway, and his supersensitive seismometer detected many earthquakes and two underground nuclear tests in Nevada, an achievement that won him college scholarships, science fair

> awards, and trips to the ISEF and the annual meeting of the American Association for the Advancement of Science. An atmospheric scientist said my daughter Vicki's attempt to detect solar x-ray flares with a Geiger counter would not work. Remembering Eric's experience, I excitedly told her this meant her project would succeed! And succeed it did, for Vicki detected six X-class x-ray flares. Her project won science fair awards and was recently published in a book. (Mims 1999)

Indeed, when motivated and given the right tools, members of the public can bring themselves up to speed quickly – sometimes surpassing the knowledge of their local authorities and experts. This is especially true in medicine; parents of seriously ill children or patients with critical conditions are availing themselves of all the resources available (libraries, support groups, the Internet, conferences, etc.) and more often than not, are coming to their doctor's office armed with more knowledge on their condition than the doctor has (Solovitch 2001).

Why the Gap?

Scientific inquiry was, by default, originally done by amateurs. The foundations for the science of the 21st century were laid almost entirely by people who did not get paid to do science – such as William Herschel who had made several vital discoveries before the king awarded him a small annual pension, or for that matter, Albert Einstein, who did some of his most important theorizing while working as a patent clerk.

Given this history, why is there such a gap between modern scientists and non-scientists? While an in-depth treatment of this question is beyond the scope of this paper, it is important to remember that the divide exists at least in part because the scientific community set out to create one.

It arose through the work of people such as T. H. Huxley and John Tyndall who campaigned for government funding, the establishment of laboratories, and salaried positions, and who also worked to purge scientific societies of wealthy amateurs, Anglican clergy, and women (Lightman 2000). The gap was widened with the creation of a system of credentials and exclusive societies that required those very same credentials for membership. It grew wider still with the adoption of a way of speaking which meant that the "history of the development of the brain" would be termed "neuroembryogenesis," while thorns became "modified setaceous processes of the epidermis" (Fayard 1992; Broks 1993). Scientists started taking great issue with ideas or concepts that are deemed either unscientific or non-conforming to current theories, especially if they came from non-scientists,[9] applying scorn and disdain in professional amounts. The divide is deep enough and culturally acceptable enough that no one thought it unusual or shocking when President Richard Nixon said of citations during an award ceremony: "I have read them, and I want you to know that I do not understand them"[10] (Greenberg 2001, 245).

[9] In his books, Carl Sagan often provides anecdotes about, for instance, how he had to disabuse his cab driver of his beliefs on UFOs or another person of their belief in angels. He admitted that this did not always come across well: "Even when it's applied sensitively, scientific scepticism may come across as arrogant, dogmatic, heartless, and dismissive of the feelings and deeply held beliefs of others. And, it must be said, some scientists and dedicated sceptics apply this tool as a blunt instrument, with little finesse." (Sagan 1996) The problem with this approach is that not only is it not likely to win any converts, but it is likely to ensure the creation of enemies. It is like kicking the crutch out from someone without first teaching them how to walk.

[10] If the President had confessed to ignorance in other matters relating to public policy, such a economics, military strategy, or foreign affairs, the public would have been shocked and probably questioned his competency for the job.

This is not to say that the establishment of professional science was a bad thing; there are good reasons for establishing credentials, standards, and codes of conduct. Scientists are certainly not alone in doing this; humans are generally inclined to create societies, guilds, associations, and groups. It is important to remember that such things are done for the purposes of separating people and that those who control membership (i.e., the existing members) are not likely to easily give up such divisions. Being a professional, after all, affords a person a higher degree of social status, especially for scientists in today's society.

This is why participatory science is an important tool. It does not require the scientific community to disband its various associations or water down the requirements for degrees so that anyone can obtain them without trying very hard. It does not bypass the peer review system. It does not involve the destruction or degradation of any of the institutions that the scientific community has worked diligently over the past two or three hundred years to set up. This is vital because even in the sciences where "new" and "revolutionary" are supposed to be part of the routine, there is often resistance to change. Participatory science, by working with established methodologies and institutions, overcomes this significant obstacle.

Quantifying the Appetite

While it is difficult to say with absolute certainty whether the public will embrace participatory science, there is ample evidence to suggest that there is a tremendous appetite for all things scientific and especially those things space related.

A quick look at the Amazon.com top 100 bestsellers, for example, at a time when US booklists are dominated by tomes about the Middle East and related domestic political issues, reveals, at number 56, Brian Greene's *The Elegant Universe,* a book about the most esoteric aspects of astrophysics: string theory. Even more intriguing is the fact that the book has been out for three years; it has had enough of a following to warrant a Public Broadcasting Service (PBS) television show on the subject. Other books, like Stephen Hawking's *A Brief History of Time* or Michio Kaku's *Hyperspace: A Scientific Odyssey through Parallel Universes, Time Warps and the Tenth Dimension*, have also made it to bestseller lists and have had TV shows created on the subjects. Books on biology, evolution, and psychology also do well, with authors such as Richard Dawkins, the late Stephen J. Gould, Stephen Pinker, and Edward O. Wilson becoming household names. Even mathematicians and mineralogists can write (and sell) books, including entire missives on the histories of the golden ratio (*The Golden Ratio: The Story of Phi, the World's Most Astonishing Number* by Mario Livio) and salt (*Salt: A World History* by Mark Kurlansky).

Scientific magazines can regularly be found in grocery store racks (*Popular Science, Scientific American, Discover),* while television stations dedicated entirely to science programming continue to proliferate. *Discovery* currently has at least seven separate channels all with 24/7 science or science-related programming (Discovery), *National Geographic* has gone from simply producing occasional documentaries to running its own station, and there have been proposals for an additional all-science TV channel (Shermer 2003).

Science news, especially when it is space related, attracts considerable media and public attention. When the Mars *Pathfinder* landed, the mission website and its mirror sites received roughly 16.2 million hits in a single day (Toporek 2003). *Dante II* was not even in space – it was just wandering around an Alaskan volcano on a test run – when its website received half a million hits in two weeks (Baker 1995). The Mars *Polar Lander*, a mission that ultimately failed, attracted more than 176 million hits in December 1999 (Mars Polar Lander 1999).

In spite of the dangers, surveys have consistently shown that the public would love a chance to fly into space. In 1993, with the *Challenger* explosion in recent memory, a survey of Japanese citizens indicated that more than 70 percent of those under 60 and 80 percent of those under 40 wanted to visit space at least once in their lifetime. Further, 70 percent were willing to pay three months' salary for the privilege. In 1995, some 60 percent of North Americans said the same (Collins, Stockmans, and Maita 1991). In a more recent poll, seven percent of wealthy Americans surveyed were willing to pay $20 million for a trip into space with the percentage increasing to 16 percent if the price tag dropped to just $5 million (Zogby International 2002).

People are even willing to do amazing things just for a *chance* at flying into space. In the 1960s, at a time when women were still expected to aspire only to be wives and mothers, women lined up for a chance to become astronauts. This was also a time when the dangers of space travel were not well known. Tests included being strapped to a table and suspended upside down, having super-cooled water injected into the ear to freeze the ear canal to induce vertigo, and being confined to a small chamber to induce claustrophobia (Nolen 2002). More recently, a "soccer mom" in the US stated that she was willing to undergo surgery to remove her gallbladder and a wisdom tooth if that was what it took to secure a seat into space (Berger 2002). Even when the field of inquiry does not have the "cool factor" that space exploration offers, it seems that average citizens are willing to go to great lengths to participate. In spite of the costs and less-than-ideal conditions noted earlier in the *Earthwatch* example, where people basically paid to do free labour, from 1971 to 1997, the institute managed to put together 1,500 expeditions in 100 countries with the help of some *35,000 volunteers* and funding in excess of $20 million (Hartman 1997).

The hunger is great enough that when people cannot participate in real science, they devote considerable time and money to vicarious science – science fiction. Consider the phenomenon of *Star Trek*: a single TV series that received lukewarm network support in the 1960s has grown into an entire universe of its own, spawning five TV series, eight movies, hundreds of novels, and thousands of conventions around the globe (Greenwald 1998). Indeed, the "franchise," as it has become known, is so popular that it has generated some *$5 billion* for Paramount Studios in ancillary markets, not including film or TV series revenues (McNary 2002). To put this figure in perspective, the money spent on licensed *Trek* goods alone equals approximately one-quarter of the proposed cost of Dr. Robert Zubrin's plan to get humans to Mars (Zubrin 1997). This does not count money spent on all other science fiction series, such as *Alien Nation*, *Babylon 5* or even *Star Wars*.

Beyond the affluent West, there is also a hunger and need for science and space exploration activities in the Third World. Nigeria, to the surprise of many, launched its first satellite in September 2003. Several authors have noted that basic science is vital to national development and that space can be a uniting factor – the skies are common to everyone. However, for a variety of reasons (lack of infrastructure, politics, discrimination), people in the Third World who are interested often find obstacles in the way of their participation in the international scientific community. This, combined with the increasing complexity of the world we live in, results in an “ingenuity gap,” and when chronic, can leave nations unable to solve their most critical problems. Participatory science projects that cross borders will provide a means for interested people in developing countries to participate, encourage the development of infrastructure where necessary, and increase scientific literacy in a non-paternalistic manner. This is especially true if the research being conducted is vital to solving the nation’s problems – people will be contributing directly to the solution (Jasentuilyana 1995; Sausen 2000; Homer-Dixon 2000; Ocampo, Friedman, and Logsdon 1998).

Stepping away from the abstract and moving to the specific, one only has to look at the number of users there have been for the participatory projects catalogued in this paper. Only one project has made any substantial, broadly based public relations efforts – Seti@Home – and to date, it has attracted more than 4 million participants. Other projects have made very little effort to publicize the work and yet still garnered hundreds of interested non-scientists; some participants, as in the Clickworkers case, stayed around and did work for weeks, even though the tasks were fairly mindless and repetitive. Obviously, the popularity of a project will greatly depend on the subject matter, the challenge, and the effort required, but there is clearly a receptive audience waiting.

Why Space Exploration Needs Participatory Science

In the course of searching for space-related participatory science projects currently in progress, one thing that became abundantly clear was that there are a tremendous number of things that *need doing*.

Consider celestial observations. New technologies and more observatories mean that data is pouring in, quite literally, in astronomical quantities. Even with a paid staff numbering in the hundreds or thousands (which observatories are never likely to reach, even with a 100 percent pro-science society, simply because other scientific disciplines also need funding), it would take decades to sort through what we have collected. This does not count the pre-CCD era photographic plates currently languishing in various back rooms around the world (Spectroscopic Virtual Observatory 2003), or the new flood of data that can be expected to come in with ever greater advancements in telescope technology.

We are also in serious need of alternative propulsion technologies. While many thousands of improvements have been made to rocket design, the basic process still involves igniting several thousand pounds of extremely volatile chemicals. At best, the process is a controlled explosion that subjects both the people and equipment on board to extreme vibration and g-force. At worst, it is deadly. The chemicals are also dangerous and toxic to handle and store.

The cost to launch anything is also prohibitive. The heavier the load or the longer the planned flight path, the more fuel is required – which, in turn, adds again to the overall weight of the craft, which increases the cost … a modern Catch-22. There is also a tremendous cost in engineering things to withstand the launch process, in terms of both time and money.

We desperately need a cheaper, faster, and safer method of getting into low Earth orbit. NASA has attempted to develop some new technologies, but budgetary and political considerations seem to have rendered it incapable of aggressively developing anything radically new. The *X-Prize* has attempted to jumpstart the process, but it is a competition, not a collaborative effort. Since its inception in 1996, only 25 teams have registered, and most of the competitors are organizations that were in the business of building rockets already (X-Prize 2001).

Given that the first rocket designs were sketched out and designed by individuals such as Konstantin Tsiolkovsky[11] and Robert Goddard, it is not a stretch to suggest that a coordinated, large-scale effort between scientists, engineers, and passionate dedicated non-scientists would result in some surprising and completely new methods for getting into space.

The same can be said of planetary science missions. Technology and off-the-shelf electronics have advanced to the point where undergraduate students can construct rudimentary working satellites – complete with GPS, communications, imaging equipment, and sensors – in ordinary soda cans (Report 2001). While genuinely space-hardy equipment must obviously be built to higher standards, it may be time to try a new approach to planetary exploration. Rather than sending single-shot probes with several different types of sensors (an all or nothing proposition that can mean that millions of dollars are wasted when the probe fails to reach its target, as was the case with the *Polar Lander*), perhaps many tiny single-purpose probes could be sent. An excellent participatory science project would be to enlist the help of all the garage and basement workshops out there to have dozens of these types of probes built cheaply and quickly.

Robotics is another area in which the average person can quite easily contribute. *Robocup*, a competition noted in Chapter 2, has as its goal the creation of a team of

[11] Here it should be noted that Tsiolkovsky worked strictly with pencil and paper, and yet managed to work out some fairly sophisticated concepts, thus proving that you do not necessarily need a well-equipped lab to get science done.

robots that can play and win a game of soccer against a human team. The show *Junkyard Wars*, now in its eleventh season (!), features ramshackle – but quite viciously capable – robots built of junk, with the goal being to beat their competitor back into a useless heap. A far more useful competition in terms of space exploration, for example, would be a robotic race over difficult terrain or remote manipulation tasks. Scientists could set the tasks depending on what advances are needed and co-author papers with the winners.

As Mars Society Canada's *Expedition One* demonstrated in Chapter 2, it is quite possible for a very small group of people to put together a complex and scientifically useful mission. By tapping into the resources and skills of all its members, both scientific and non-scientific, the group managed to raise funds, purchase equipment, invent equipment, organize a complete program of study, and produce nearly a dozen papers – all during its first ever attempt to conduct such an expedition. A second expedition is now being planned for a station in Australia using the same principles. It is an excellent example of what a space advocacy society can do when it encourages its members to do more than just pay their dues and read a periodic bulletin.

Finally, space age history is a wide-open field, with relatively few people working to produce comprehensive accounts. For obvious reasons, most of these are focused on US and Russian efforts, and a fairly substantial volume of this work has centred on the technologies and machinery involved. Launius has suggested a number of different political, social, and cultural angles that need to be researched (Launius 2000), and certainly the time has come to more thoroughly document the contributions of other spacefaring nations such as Canada, the members of the European Space Agency (ESA), Japan, China, and India. Amateur space historians could make significant contributions here.

Why Space Advocates Are Ideally Positioned to Organize Participatory Science Projects

With the possible exception of medical support groups, space exploration advocates are probably in the best position to organize participatory science projects.

First, space is both naturally and culturally attractive. For centuries, people have looked up and wondered about the stars; in recent centuries, speculative accounts – some wild, some sober – of what might be “out there” have fired the public’s imagination (McCurdy 1997). As advocates are fond of pointing out as well, the benefits of space exploration are legion. Space, except to the most curmudgeonly and shortsighted, should not be a “tough sell.” In contrast, while medical projects are not a tough sell either, generally the cause and support are specific. For example, cancer research appeals to people who have cancer or relatives and friends of those who have it. Space is not only far more universal, it does not have the unfortunate negative connotations.

Second, because space exploration and advocacy have been around for decades, there are already several well-established organizations that have both the money and the resources to organize such projects. There are the major space agencies, such as NASA and the ESA, that are well funded. There are the up and coming agencies, such as the Chinese and Indian agencies, which, even if not well supported financially, certainly have access to vast numbers of intelligent and skilled potential participants. Other non-governmental organizations, like the United Nations Office for Outer Space Affairs, have both the resources and funding for organizing such things.

There are also dozens of grassroots space advocacy societies, which are already populated with a good mix of scientist and non-scientist members. These include America's National Space Society, the British Interplanetary Society and Eurisy in Europe.

In addition, there are at least two educational institutions in the world with programs specifically dedicated to broadly based, interdisciplinary studies in space exploration: the International Space University in France and the University of North Dakota in the US. There also hundreds of more specific programs in aerospace, medicine, psychology, etc., that could be good launching points for participatory science projects.

Industry should also consider organizing, or at the very least, sponsoring participatory science projects. Indeed, doing so would be a good way to spur research and development, help executives source for talent that might be worth hiring, and develop new markets for products.

Chapter 4 – Directions for Future Research

This paper was inspired by two major questions. The author has considerable experience in space advocacy societies at the local, national, and international levels, usually holding positions in membership or public relations. Over time, it became very apparent that in any association, while there was usually a core group of people who could find tasks to occupy their time, the bulk of the membership had *nothing to do* apart from paying membership dues, answering petition calls, or perhaps engaging in administrative work like starting a new local chapter. Here were large groups of people inspired by *Space! Rockets!* and *Galaxies far, far away!* and we were offering them … pamphleteering. Consequently, membership retention over the long term became a problem. The question then became, *Can't we offer them something better?*

At about the same time, the author became aware of the Seti@Home program and the response it was generating. The statistics were fascinating – not only had millions signed up, but they had signed up from everywhere: Malta, Lichtenstein, Djibouti, and even the Faeroe Islands. This raised the question, *Why are we not doing more of this sort of thing?*

The answers to both questions, as it turned out, were more complicated than they had first seemed. This paper has attempted to lay out the context for participatory science – Why is it needed? Why has it not been done very much in the past? – and establish a formal definition for it. In other words, this paper has set out to establish a need, identify a solution, and name key players who could implement participatory science.

This is just the beginning, however. If we are to use this methodology to its full potential, much more work needs to be done. Here is what the author intends to pursue based on the results of the survey of existing projects:

Establishing Measures of Success

To determine if a participatory science project is successful, we need to determine how best to measure success in context. At least part of the determination will obviously be based on the initial goals set up for the project. If the goal of a project is to review a large but finite set of photographic plates for evidence of undiscovered comets, and all the plates are reviewed and some comets discovered, then the project is at least partially a success.

There are other factors to consider, however, and these are important if we are to learn how to make good participatory science projects better. These factors include:

Public relations success. Since the secondary goal of a participatory science project is outreach and education, this must be measured. Questions that need to be asked are: How many participants did the project attract? How many casual observers? Before, during, and after the project, how many people heard about the project or the issues associated with it? What steps (press releases, interviews with major players, book releases, Hollywood tie-ins) were taken to publicize the project? Which were most effective and why?

Scientific success. There are several ways to measure scientific success. The most obvious way would be to make some major discovery or breakthrough, but as much as everyone dreams of such things, they are relatively rare. Questions to ask in this category would include: How much data was collected or analyzed? What was the quality of the data collected or of the analyses? How can data quality be improved? Was the rate at which data was collected and/or analyzed satisfactory, or could it be improved? Were the raw data and analyses made available to the public domain? Did the entire process, from start to finish, meet with the standards of a typical peer review? Did the project have scientific merit in the first place? Will the knowledge gained from the endeavour be worth the effort? These are all difficult but necessary questions.

Participant Satisfaction. This is probably the most important set of measures to review if participatory science projects are to attract and retain participants in current and future projects.

Did the participant feel as if he/she contributed in a real and meaningful way? If someone is going to dedicate time and effort to a project, he/she must get the sense that what he/she is doing is worth it and that it is vital to the project's success.

Did the user's overall scientific literacy increase during the course of his/her participation? Did his/her knowledge of the science behind the project increase? In short, did he/she learn anything as a result of his/her participation? As noted in the definitions in Chapter 1, participants should not simply be assigned a task without any background or context; they should be made aware of what they are doing and why.

Did the participant feel the work was challenging? Too challenging? Too easy? The Clickworkers project was interesting because participants were looking at real images from Mars probes, and training took less than a minute. On the other hand, the task – identifying a crater by click-drawing a circle around one in the picture – quickly became tedious and repetitive. Indeed, about 37 percent of the data came from one-time visitors to the project (Clickworkers). Frustration can also arise when the learning curve is too steep. Project designers must determine if participant frustration stemmed from the science involved or the participant interface, and make the work challenging without being too hard to understand in a reasonable amount of time.

Did the participant get any recognition for his/her work? Monetary compensation is clearly not going to be available for every participatory project, although it should not be entirely ruled out. Even if wages or salaries are out of the question, honorariums, or awards for excellence, should be considered. Project designers should at the very least (with permission, of course) publicly recognize all participants by publishing names on a website or in an advertisement and/or reference particular contributors in journal articles where their efforts warrant it.

Identifying and Mitigating Potential Problems

Participatory science will not be without certain pitfalls. There are several issues that need to be investigated and measures taken to mitigate any problems.

Legal issues. One of the unforeseen problems with the Seti@Home project came from the use of resources. David McOwen, a computer technician at DeKalb Technical College in Atlanta, Georgia, US, installed the program on computers there without first seeking official permission. That earned him charges of computer theft and computer trespass, threats of a fine of up to $415,000, and potential jail time of anything from eight to 120 years in jail. At the Tennessee Valley Authority in a similar case, 18 employees were summarily sacked for running the software on their computers (Hermida 2002). One could argue that both cases were extreme overreactions that could easily have been remedied in less acrimonious fashion; nevertheless, obviously some employers take a particularly dim view of the use of company property, and this must be considered in the design of any participatory science project. In a related issue, researchers have discovered how to coerce computers into doing science without the consent of their owners. While the intent is good – turning the web into one big supercomputer for the purposes of speeding research – so called "parasitic computing" is definitely loaded with legal, moral, and ethical issues. These and other legal considerations must be examined, preferably before well-intentioned participants end up in the courts.

Morals and Ethics. Non-scientist participants, just like their scientist counterparts, have certain moral and ethical value systems. These may conflict with the eventual use of the results produced by a participatory science project. Participants may withdraw their support if they object to the use of their work; they may also somehow attempt to stop the use of their work by legal means. Although it is difficult to see how this would be attempted, intellectual property laws and rules governing biological issues are still very much in flux at the moment and these could be significant issues.

Technology transfer. Space activities and the military have always been connected. The same technologies that are used to launch rockets can be used to launch missiles; satellites can observe weather patterns or provide strategic reconnaissance. Participatory science project designers must consider the nature of their research and decide ahead of time as to what, if any, aspect of the research can be made public and to whom it can be made so. In this era of instant communication via phone, fax, and the Internet, it should be assumed that data or knowledge released in one country will quickly make its way to other countries. The public is global.

Data quality. While Joe Public can be smarter and more reliable than is often thought, he can also be careless or misunderstand. Project designers must find ways to build quality control checks and redundancy into their research. The model used should be rigorous without being so redundant as to be inefficient.

Equal opportunity. Another problem will be to make the projects as accessible to all as possible. The drawback of something like SETI@Home is that only those people with a reasonably up-to-date computer and a reliable Internet connection can participate. This is not just a matter of egalitarianism; the point is to try to tap into the deepest, broadest wellspring of talent as possible. Obviously no single project can be made available to all people, but some effort should be made to offer a variety of participation modes.

Amateur acceptance and self-confidence. Scientific inquiry can be a rough and tumble business. Even extraordinarily well-qualified professionals with dozens of peer-reviewed papers, awards, and contributions to their names can find themselves the subject of an intense, discipline-wide attack should they propose a new theory that runs contrary to the current paradigm. Even in the most equitable participatory science environments, non-scientists are likely to be keenly aware of their lack of official credentials and will find it hard to maintain confidence in their work, even with good data behind it.

Concept resistance. Given the usual tendency to resist change combined with some of the potential issues raised in this chapter, some parts of the scientific community may be less enthusiastic about the concept than others. The best way to overcome this will likely be to put together projects that work well, do good science, and help raise scientific literacy. The results will speak for themselves, as all good data do.

Conclusion

In order to get somewhere, we have to know where it is we want to go.

One of the fundamental problems with space exploration advocacy is that we have lost our focus. We probably went to the Moon for all the wrong reasons; US President Dwight Eisenhower likely had the right idea when he resisted a crash program to get to the Moon, favouring instead a more thoughtful path into the heavens. It is as though, after focusing so intensely for an extended period of time on the single goal of beating the Soviets to the Moon, we have been unable to focus on any other goal in space ever since. Ask twenty space enthusiasts where we should go next, and you'll be pointed in twenty different directions. Nevertheless, this is the legacy that space advocates have been left, and we must deal with it.

The same problem exists in the study of the public understanding of science. To date we have not been able to clearly define what it is we mean by "public understanding." To say that we want public *appreciation* of science implies that we would be happy with a blank cheque from Joe Public and a lifetime in the lab, unmolested. That is likely the most truthful definition we can offer, but it is also the least realistic. To say that we want nothing more than for the public to understand science for its own good is also a bit too altruistic a motive to be truly believed.

What, then, is our vision of the future?

For the scientific community as a whole, it is safe to assume that the best of all possible worlds would be one in which the majority of the public was scientifically literate. This would be a world where knee-jerk reactions, such as, "You must not do this research because it tampers with the Natural Order of Things," are replaced with more thoughtful criticisms like, "Have you considered what will happen with *X* when you do this, and if so, how do you plan to deal with this?" It would be a world where researchers would still have to compete for funds (because that aspect of life probably *is* in the Natural Order of Things), but would have access to a vast pool of talent and energy that would enable them to get things done more cheaply and possibly even on a larger scale. It would be a place where both professionals and amateurs could just do more science.

For the space advocacy community, the ideal would probably be a sustained, coordinated program of both robotic and manned exploration, involving all the spacefaring nations. At this point in the Space Age, even the most fanatical Mars advocate would be in favour of a lunar outpost by 2010 if it meant our first manned foray to Mars was *definitely* on the agenda for 2015 or even 2020. More importantly, however, the ideal world for space advocates would be one where they were not relegated to watching launches on TV or downloading Hubble space telescope images to use as computer decor. It would be a place where they could actively reach for the stars even if they cannot secure a seat on the next flight out just yet. Vicarious no more.

Participatory science, as defined in this paper, may be the key to bringing this ideal world into reality. It is a method for conducting science. It is a social instrument that will help bridge the widening gap between the scientists and the non-scientists. It is a pedagogical approach based on the most effective teaching methods we know:

Tell me and I will forget.

Show me and I will remember.

Involve me and I will understand.

Metaphorically speaking, it is time for space advocates, whose philosophy is supposed to involve the adoption of new ideas, new technologies, and new methods, to set aside their model rockets and start building real ones.

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