AIAA SPACE 2007 Conference & Exposition
18 - 20 September 2007, Long Beach, California

AIAA 2007-6208

Opening Space for Humanity - Applying Open Source Concepts to Human Space Activities

Paul D. Wooster*, Willard L. Simmons†, and Wilfried K. Hofstetter‡
DevelopSpace Initiative, Inc., http://www.developspace.net

With the open source paradigm gaining traction in a variety of fields, the question arises as to in what ways open source concepts can be applied towards space development endeavors. This paper examines the potential for applying open source towards human space activities. We find that open source holds much promise for benefiting space development endeavors. Open source can clearly be applied in the space software area, including modeling and design tools, testing, ground software, and flight software. The paradigm can, however, be extended beyond software, in areas such as system design, compilation of reference data, system verification & validation procedures and associated results, and relevant education and training materials. Many individuals around the world are highly motivated towards contributing to the expansion of humanity into space. Applying open source principles towards space activities can provide them with a means of doing so. A new organization, DevelopSpace, has been created to aid in the advancement of such activities, focused on building up the technical foundations for human space activities, and doing so in an open manner.

I. Introduction

THE exploration of space is something that captivates a great many people around the world. Human expansion into space captivates yet more people. Some are motivated to propagate the species and ensure its survival generations into the future, while some are intrigued by the scientific aspects of exploration and the opportunities for discovery. Some people are interested in using space to directly and materially improve life on Earth, while some see it as an amazing technical challenge. Some see space as an opportunity for entertainment and personal fulfillment, while others see space as offering inspiration and stories of great accomplishment. Space resonates with people in many distinct ways.[1-5]

Exploring and expanding humanity into space is a challenging endeavor. Many intertwined obstacles must be overcome in order to make this happen. Some of these barriers are *financial* in nature, in terms of being able to provide sufficient resources to both initiate and sustain human activities in space. Some are *political* or *public* in nature, revolving around gaining and maintaining public and political support to allow such activities to move forward. Others are primarily *technical* in nature, involving the design, development, and operation of the systems required to transport humans into space and support them there. These aspects of space development are interrelated – overcoming technical barriers requires financial resources, gaining financial resources requires government or private investment, and government support requires public interest. Additionally, government regulatory concerns may cause barriers to entry for private investment. To make matters worse, once a technical barrier is overcome, it is frequently kept in-house by its developer so that no other entrant to the challenge can use it or improve on it without re-creating the solution all over again. Arguably, these barriers have reduced the speed of progress in human space exploration significantly since the days of rapid progress in the 1960's.

We propose the use of the open source concept as a way of building the technical foundations for human expansion into space. This approach will reduce some of the aforementioned obstacles by making use of the contributions of the many interested individuals all around the world. A vibrant open source space development community will catalyze the exploration of and humanity expansion into space.

* AIAA Member, paul@developspace.net.
† AIAA Student Member.
‡ AIAA Student Member.

II. The Open Source Concept

The open source paradigm has caused major shifts in the way that software is developed, tested, used, maintained, and enhanced.[24,25] A significant fraction of the infrastructure underpinning the Internet is based upon open source software, and a number of major commercial open source software projects exist for creating a wide variety of professional software applications.[12] As just one example, SourceForge.net, a major open source software portal has over 1.5 million registered users and close to 150,000 projects.[6,18-20] The open source concepts fostered in the software realm are also now transitioning to a variety of other fields. One example is Wikipedia, a free encyclopedia, which features user generated content under a free/open source license; Wikipedia has grown to include millions of articles in over a hundred languages.[7] Another example is MIT's OpenCourseWare initiative that aims to put all of the educational materials from the university's undergraduate- and graduate-level courses online, free and openly available to anyone, anywhere.[8]

In this paper "open source" is used to refer to creative works either released into the public domain or copyrighted and then licensed in such a manner as to allow the free use, modification, and redistribution of either the original or modified work, possibly including clauses mandating any redistribution of the work be licensed under like terms. The term open source originated in the software world where it came into use to describe software developed and released in an open manner with the source code licensed under open source terms. The GNU General Public License (GPL) and the GNU Lesser General Public License (LGPL) are two examples of popular open source licenses. These licenses are published by the Free Software Foundation (where "free" refers to freedom, as opposed to being without cost), which also maintains a listing of other free and non-free software licenses.[9] The Open Source Initiative also maintains a listing of software licenses that meet their Open Source Definition.[10] Options also exist for licensing works other than software in an open source manner. The Free Software Foundation also publishes the GNU Free Documentation License (FDL), which as the name implies is aimed more towards written works. This is the license used for the articles on the popular Wikipedia website. The Creative Commons also maintains a set of licenses which can be used for a variety of copyrighted works; some of the Creative Commons licenses (although not all) can be considered open source in nature (the Creative Commons-Attribution and the Creative Commons-Attribution-Share Alike licenses without further restrictions in particular meeting open source principles).

Developing and releasing materials in an open source manner offers a variety of significant benefits. It provides a means to leverage the contributions of many individuals and groups to create significantly larger, more comprehensive works than any of them would have the resources to do alone. The ability for many people to review and improve on the information at hand yields increases in quality due to the "massively parallel peer-review" which takes place. In addition, due to the ability to infinitely replicate open source information at little to no cost, many more people are able to make use of the information that has been generated, and thus derive benefit from it, than would have otherwise been possible.

As open source spreads further beyond the software realm, to include everything from encyclopedias to architecture,[7,11-12] it is worth considering in what ways open source principles can be applied to space endeavors. Open source has transformed many of the fields it has encountered, and it may very well do the same for space exploration and development. In the remainder of this paper we examine the potential for applying open source to space development.

III. The Potential for Open Source Space Development

Focusing on the technical aspects of space development, one can consider the many items which must be completed in order to accomplish a given objective. Extensive technology development, analysis, design, prototyping, testing, and so on, may be needed in order to create a space system (manned or otherwise) and establish its operational readiness. The effort that goes into each of these activities is a significant driver of the cost of an overall endeavor. In addition, as these efforts are completed, not only does the total remaining investment required decrease, the level of additional investment required is better characterized along with an increased understanding of what directions are likely to prove fruitful for subsequent efforts. Efforts focused towards developing more generalized tools and techniques can also be beneficial by catalyzing subsequent efforts, making them more effective.

While specific technical challenges are in some cases unique to an individual project, in many cases the majority of challenges represent obstacles that have been overcome in previous projects. However, frequently the particular solutions to these challenges are not widely available. Even with documentation presented in papers, journal articles, and contract reports, significant information related to the technical solution (such as detailed assumptions, models, designs, and software code) is frequently not readily available, particularly so in a form that is easily used (such as a software source code in a machine readable form or a 3-d model of a design in a CAD file). As such, identical work is often repeated across space endeavors, increasing the cost, developmental risk, and operational risk due to the inherent cost and risk of developing and operating a new, unproven system. By instead providing information required to overcome the technical obstacles inherent in all space activities in an open source manner, the technical foundations for human space activities can be incrementally increased over time more effectively, and with significantly decreased need for duplication of effort and associated customization.

The fundamental promise of open source space development therefore is that new space activities can be initiated more quickly and for lower cost and risk than under traditional space development paradigms.[13-15] Opportunities for international collaboration and the inclusion of contributions from individuals around the world in space activities are also greatly increased under this model, thereby greatly enlarging the intellectual resource base for the advancement and development of human space endeavors.

Significant activity is already underway around the world in government, academia, industry, and the non-profit sector towards advancing the human exploration and development of space. Unfortunately, much work is frequently duplicated from activity to activity, or may not be focused in a direction completely relevant to the problems at hand. These influences can limit the real contribution that new work makes towards advancing humanity into space. Providing a platform that archives and organizes available information and results from past studies and development project could aid in avoiding duplicate work, particularly in so far as the information made available is comprehensive (including models, source code, designs, etc.) and made available in a manner that can built upon easily. Similarly, being able to identify specific directions for further work can help focus such work so that it makes a true contribution to the field.

Although a number of people are engaged in relevant work on a variety of fronts,[21-23,26-29] there is significant work that remains. Many people around the world have skills relevant to advancing the human exploration and development of space, including a great many who are not currently involved in doing so. One need not be an aerospace professional in order to contribute towards the technical aspects of space development. Opportunities abound for mechanical engineers, electrical engineers, chemical engineers, roboticists, and computer scientists, amongst many others. Machinists, welders, and technicians can provide valuable expertise in prototyping and testing system and sub-system designs. In many cases individuals with pertinent skills and an excitement about space are available, but they simply do not have an opportunity to or are not aware of how they can contribute[§]. Providing a means for them to both make technical contributions and understand in what ways they can contribute is thus quite valuable.

Understanding that opportunities exist to contribute can also serve as a motivating factor for those who do not yet have necessary skills. Much effort is put into space related educational programs, aimed in part at motivating students to study technical and scientific fields. Having an opportunity to make a meaningful contribution towards space exploration and development provides an inspiration and incentive for individuals to learn the math, science, and engineering skills involved in so doing. The availability of open source materials can also aid in education beyond the motivational aspects by providing readily accessible examples that can be studied in detail, aiding in learning how such systems work and are developed. As individuals contribute to the space development activities they will also gain experience and benefit from significant "learning by doing."

Through these means, a vibrant open source space development community can gain additional contributors. These contributors, by being actively involved in the development of space, will have a significantly greater personal investment in space activities. This investment will likely translate to increased support, both financially

[§] A variety of space advocacy organizations provide opportunities for individuals interested in space to contribute through political and educational outreach along with financial contributions.[31,32] While useful, these methods do not fully capitalize on the resources the individuals themselves can bring to bear on the problems at hand, namely in terms of their time, energy, and technical and intellectual abilities.

and politically. As such, beyond simply providing technical progress, open source space technical activities can further aid in addressing the other barriers to humanity's expansion into space presented earlier in this paper.

IV. Open Space Development Business Influences

Over the longer-term, transitioning to an open source model may also cause shifts in the way that space development activities are conducted more generally. With a large base of generally available knowledge resources to draw upon, development will be less tied to the internal proprietary information of any given company. One can make a strong argument that given the public funding behind government space endeavors, the results of such activities should be shared as broadly and openly as possible. Similarly, in so far as academia is intended to promote the development and dissemination of knowledge, embracing open source principles should be well suited to its activities. Industrial entities may be more reluctant to fully embrace open source models, and possibly at first focus on reaping the knowledge created in an open source manner while limiting the contributions back. While this reluctance to contribute may be a natural phase in the evolution of an open source space development ecosystem, it is worth noting that a multitude of profitable business exist which are significant contributors to open source software.

The Eclipse integrated development environment software project is a good example (out of many) from the open source software world of how competitive business can be supported by open source development. Eclipse is a platform that provides software development infrastructure and tools created in 2001 as a for-profit software consortium by IBM, Red Hat, and other companies. In 2004 Eclipse was converted into a non-for-profit corporation and the Eclipse software platform was released into open source. The Eclipse open source community today consists of private individuals who are motivated by personal interest, as well as a significant number of members that are also employees of the companies that originally founded Eclipse and support the non-for-profit corporation today. These "professional" members are required by their companies to spend part of their paid time on Eclipse to contribute to infrastructure development crucial for the company's applications. By releasing Eclipse to open source, the individual companies that founded Eclipse were able to reduce their infrastructure development and maintenance costs by spreading them over a large community, part of which is essentially working for free (gaining benefits through recognition of their work and the availability of a higher quality tool that better meets their needs), and part of which is paid for by other companies. It is interesting to note that some of the companies that are part of the Eclipse consortium and work together on infrastructure development are competing with regard to the application software that is based upon this infrastructure.[12]

This example illustrates how open source development of underlying foundations and infrastructure does not necessarily rule out competition on a different level: companies that work together on the development of fundamental human space flight design, development, and testing *infrastructure* in an open source manner could still compete on the contracts for the detailed design and implementation of a specific system. The open source concept may, however, allow each company to reduce their developmental expenses by leveraging work provided by the open source community. In addition, given that much of the funding for human space endeavors comes from government sources, these cost savings translate into opportunities for additional achievement within the funding levels provided by any given government.

V. Creating an Open Source Space Community

Information technologies are advancing rapidly and can enable space development-related collaboration. Tools can be readily developed to enable the sharing of models, tools, methods, results, designs, and other knowledge. Doing so will enable an individual or group to build upon earlier work more directly and will provide greater focus as to what work is worth engaging in.[16,17] Having such a common, open source resource-base on which to draw will allow government, industry, and academia to focus on the truly innovative aspects of their endeavors, rather than having to recreate existing capabilities. This will enable significantly more progress to be made within existing resources, and also tend to make additional resources available due to the increased support engendered by increased participation.

While some open source space-related endeavors have occurred to date[13], having an organization dedicated to promoting and providing the infrastructure for such activities will be quite beneficial. The authors of this paper are among the founders of DevelopSpace, an organization committed to making this happen.[30]

The overall goal of DevelopSpace is to build-up the technical foundations for human space activities. DevelopSpace is a non-profit organization chartered to engage in scientific and educational endeavors with a focus on open sharing of relevant technical resources and fostering related technical activities and innovations. DevelopSpace will enable a wide variety of individuals and groups to participate in the exploration, development, and utilization of space and thus build a sustained community working towards human expansion into space.

The focus for this open source space development community is DevelopSpace.net. Just as SourceForge does for open source software and Wikipedia does for general, encyclopedic knowledge, DevelopSpace.net will provide a platform to host open source space projects and will serve as a knowledge base on space-related technical topics in general. Projects taking advantage of the DevelopSpace.net platform will be able to make use of a common set of functionality and utilities to enable a wide variety of individuals to contribute effectively to the project's goals. The capabilities of this platform will expand as time goes on, and will allow project members to focus on the space technology challenges at hand, rather than the creation and administration of the tools required for broad-scale collaboration. Similarly, the knowledge base and library amassed on DevelopSpace.net, built out of the open contributions of individuals and groups, will provide valuable information sources for those seeking to learn more about and contribute to further human expansion into space. As lessons and techniques are learned, they can be incorporated into this knowledge base for further use by others. Similarly, through the DevelopSpace community, as well as the needs presented by various projects, potential contributors can learn where their skills are needed or what skills they should be gaining, in order to focus efforts towards making meaningful contributions in progressing humanity into space.

VI. Conclusion

This paper investigated the applicability of the open source concept to the development of space, in particular for the human exploration of and expansion into space. Given the strong and multi-faceted fascination that human spaceflight continues to exert on humans all over the world, there is a potentially large number of individuals and organizations that are motivated to contribute to the advancement of human spaceflight capabilities. As a new organization, DevelopSpace is striving to foster a community of individuals and groups contributing in an open source manner to human space activities. Such contributions can provide significant technical foundations for on-going and future space endeavors. Providing well defined opportunities to engage in human space endeavors will provide a strong motivation for individuals to gain relevant skills and will result in increased numbers of individuals with a personal investment in space – meaning an increase in overall support for space endeavors.

Acknowledgments

We would like to thank all of those involved in DevelopSpace, and who have made open contributions relevant to human expansion into space. We would also like to thank all of those who do so in the future. Particular note should be given to those building the community and the infrastructure which will make this progress possible.

References

[1]Tyson N., dG., Why America Must Explore Space, http://www.parade.com/articles/editions/2007/edition_08-05-2007/Space.
[2]Zubrin R., The Case for Mars, Free Press, 1997.
[3]O'Neill, G., Dyson, F., The High Frontier: Human Colonies in Space, Apogee Books, 2000.
[4]Lewis, J. S., Mining the Sky, Basic Books, 1997.
[5]Griffin, M., Why Explore Space?, NASA, January 2007.
[6]www.sourceforge.net
[7]www.wikipedia.org
[8]http://ocw.mit.edu/index.html
[9]http://www.fsf.org/licensing/licenses
[10]http://www.opensource.org/docs/osd
[11]http://www.openarchitecturenetwork.org/
[12]http://www.eclipse.org/org/
[13]Wooster, P., Boswell, D., Stakem, P., Cowan-Sharp, J., Open Source Software for Small Satellites, SSC07-XII-3, 21st Annual AIAA/USU Conference on Small Satellites
[14]Boswell, D.W., "The Software of Space Exploration", http://www.onlamp.com/pub/a/onlamp/ 2006/03/30/software-of-space-exploration.html
[15]Byrne, D.J., "Open-Source Software and Its Role in Space Exploration", http://www.cio.com/article/111950

[16]DevelopSpace Open Source Engineering Tools project website, http://www.developspace.net/wiki/ Open_ Source_Engineering_Tools
[17]Berndt, J.S., "A Survey of Selected Open Source and Freely Available Software for Engineering and Science, and for Education, Home, and Work," AIAA Houston Horizons, Volume 31, Number 3, January-February, 2006
[18]Java Astrodynamics Toolkit (JAT) website, http://jat.sourceforge.net/
[19]Gaylor, D.E., R.C. Page III, and K.V. Bradley, "Testing of the Java Astrodynamics Toolkit Propagator," AIAA-2006-6754, AIAA/AAS Astrodynamics Specialist Conference and Exhibit, 21 - 24 August 2006, Keystone, Colorado
[20]Open-Source, Extensible Spacecraft Simulation And Modeling Environment (Open-SESSAME) project website, http://spacecraft.sourceforge.net/
[21]Turner, A.J., "An Open-Source, Extensible Spacecraft Simulation And Modeling Environment Framework", Master's Thesis, Virginia Polytechnic Institute and State University, September, 2003
[22]Turner, A.J., and C.D. Hall, "An Open-Source, Extensible Spacecraft Simulation And Modeling Environment Framework," AAS 03-501, AAS/AIAA Astrodynamics Specialist Conference, Big Sky, Montana, August 3-7, 2003
[23]NASA Goddard Space Flight Center FlightLinux website, http://flightlinux.gsfc.nasa.gov/
Open FlightLinux project website, http://www.openflightlinux.org
[24]Fogel, K., Producing Open Source Software: How to Run a Successful Free Software Project, http://producingoss.com/, 2005
[25]Warms, A., J. Cothrel, and T. Underberg, "Return on Community: Proving the Value of Online Communities in Business," http://www.interaction-ivrea.it/courses/2002-03/conncomms/docs/wp-returnoncommunity.pdf
[26]NASA CosmosCode project website, http://www.cosmoscode.org/
[27]Moran, P.J., "Developing An Open Source Option for NASA Software,"
http://www.nas.nasa.gov/News/Techreports/2003/PDF/nas-03-009.pdf
[28]NASA Goddard Space Flight Center Open Source Software, http://opensource.gsfc.nasa.gov/
[29]NASA Ames Research Center Open Source Software, http://opensource.arc.nasa.gov/
[30]DevelopSpace Initiative project hosting and reference website, http://www.developspace.net
[31]http://www.nss.org/
[32]http://www.marssociety.org/portal