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RFI Solicitation Title:	Flagship Technology Demonstration RFI
RFI Solicitation Number:	NNH10ZTT003L
RFI Section:	9 – Innovative Architectures
Synopsis:	Through the adoption and incorporation of open source principles, the FTD missions can be accomplished more efficiently and cost effectively.
Responding Organization:	DevelopSpace Initiative, Inc.
Company Address:	2502 Grand Summit Road Torrance, CA 90505
Point of Contact:	Paul Wooster
Telephone:	617-448-5684
Potential Partnership:	Non-profit, tax-exempt US corporation
Availability for Site Visit:	See http://developspace.net/

Summary

This document is submitted by DevelopSpace Initiative, Inc., a non-profit, tax-exempt corporation dedicated to supporting open source space endeavors, in response to Section 9: Innovative Architectures of the NASA Flagship Technology Demonstration RFI.

We recommend that NASA make use of open source development methodologies as an innovative organizational architecture for use in the FTD missions and NASA technology activities more broadly.

Specific actions NASA and the FTD program can take in this regard include:

- Release designs and data related to technologies, tools, and systems developed under the FTD program in an open source manner
- Seek and facilitate the inclusion of contributions from sources outside of NASA civil servants and contractors formally involved with FTD projects, including from non-traditional sources
- Actively promote and assist in the expansion of open source space development communities
- Have civil servants spend some portion of their time contributing to an open source community and allow them to use a portion of that time interacting with and contributing to an area outside of their primary project focus
- Incentivize open source distribution of information (such as designs, data, tools, etc.) by including it as an evaluation factor for proposals to the Flagship Technology Demonstration program

Doing so will yield a variety of benefits such as:

- Speeding adoption of the demonstrated technologies in the commercial sector and subsequent government endeavors
- Facilitating interoperability amongst systems developed by various parties by providing an agreed to, open, standard interface which all players can make use of
- Enabling contributions and enhancements from organizations and individuals not directly involved with the particular FTD project, but who otherwise have an interest in the topic at hand and relevant expertise to bring to bear
- Expanding the impact of the missions conducted under the FTD program by broadening the base of organizations and individuals making use of the data produced under the program

Introduction

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. To make matters worse, once a technical barrier is overcome, it is frequently kept in-house by its developer, either as an intentional business strategy or simply due to the lack of broadly released information, limiting the extent to other entrants to the challenge can use the technology 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.

NASA's proposed FTD missions aim to reduce or eliminate some of those barriers, in particular with regard to technological and operational challenges, thereby building foundations for human expansion into space, be it through the development of new propulsion, life support, autonomous rendezvous & docking, cryogen storage, high-closure life support, Mars entry descent and landing, or other technologies. We propose open source development methodologies as an innovative organizational architecture complementary to NASA's efforts for building these technical foundations for human expansion into space. This approach will help to reduce the aforementioned barriers for the initial FTD missions as well as following missions by utilizing the creativity and expertise of a large community of interested and qualified individuals and organizations to find better and more innovative solutions to technological challenges, and by making results of technological and operational progress available to the space community at large so that subsequent efforts and missions can directly build upon their predecessors.

The open source concept

The open source paradigm has caused major shifts in the way that software is developed, tested, used, maintained, and enhanced. 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. As just one example, SourceForge.net, a major open source software portal, has over 1.5 million registered users and over 230,000 projects. The open source concepts fostered in the software realm are also 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 several million articles in over a hundred languages and serves as a major source of reference material for people around the world. Another 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.

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 widely reproduce 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.

It is worth noting that open source development is not solely the domain of volunteers and individuals working on projects in their spare-time. Significant commercial involvement drives a number of open source projects, with employees of various companies being paid to develop software, release it in an open source manner, and participate in the relevant communities associated with those software projects. As one example, IBM makes significant contributions to a number of open source software projects, including the Linux operating system and the Apache web server. These and other commercially supported open source software projects run in many mission critical applications across the Internet and global information systems more generally.

As open source spreads further beyond the software realm, to include everything from encyclopedias to architecture, 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. This response describes methods by which NASA can adopt an open source development methodology for the FTD program, and the benefits of doing so.

An open source space development community for the FTD program

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 such as flying a Flagship Technology Demonstration mission. Extensive technology development, analysis, design, prototyping, testing, and so on, will be needed in order to create the space system required to test each of the six targeted technologies and establish its operational readiness. The effort that goes into each of these activities is a significant driver of the cost of the 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 during the initial FTD missions can also be beneficial by catalyzing subsequent efforts, making them more effective.

While there are specific technical challenges unique to each of the targeted technologies, in many cases the challenges are similar to obstacles that may 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 expanded upon (such as software source code in a machine readable form, a 3-d model of a design in a CAD file, and raw test data). As such, identical work may have to be repeated to complete the FTD missions, increasing the cost, developmental risk, and operational risk for each project due to the inherent cost and risk of developing and operating a new, unproven system. However, if NASA invested into providing information required to overcome the technical obstacles inherent in all space activities in an open source manner at the beginning of the FTD project development, the technical foundations for future FTD missions and human space activities can be incrementally increased over time more effectively, and with significantly decreased need for duplication of effort and associated customization.

Open source space communities could also contribute by hosting and analyzing data returned from missions. In addition the community could design and vet specific open source analytic tools to process and analyze the data returned. Once the community had the tools and the data online, collaboration could occur that would result in more analysis of the data at no additional cost to NASA. This would also increase the chance of unique discoveries in missions where far more data is generated than can be fully analyzed within the nominal mission budget.

The fundamental promise of open source space development for FTD missions therefore is that new space activities can be initiated more quickly and for lower cost and risk than under traditional space development paradigms, and result in more impactful outcomes. 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 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, including efforts related to the fields of interest for the FTD targeted technologies. 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 projects 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. In other words, by participating in a coherent open source community, the FTD program can better organize and benefit from this type of research.

Although a number of people are engaged in relevant work on a variety of fronts related to the FTD missions, there is significant work that remains. Many people around the world have skills relevant to advancing the progress of each of the FTD missions and

technologies, including a great many who are not currently involved in doing so or who would have an opportunity to contribute as part of a typical procurement activity. 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 the 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 related to the FTD program 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." A further discussion of how open source space activities can contribute to public outreach and participatory exploration is included in our response to Section 10.

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 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 response.

In addition to the direct benefits for the FTD program, establishing and supporting an open source approach will provide broader benefits to NASA. Examples include the speeding the adoption of the developed technologies in commercial sector and in subsequent government endeavors and facilitating interoperability amongst systems developed by various parties by providing an agreed to, open, standard interface which all players can make use of.

Specific benefits of an open source approach to the development and operation of FTD missions include the following:

- Contribution towards FTD Goal 2 (develop a sustainable cadence for flagship demonstrations that enable future space exploration activities): one of the driving

factors in sustainability clearly is affordability (objective 2-4). Open source space development offers the promise of reducing the cost of innovation (analog to the effects of open source development in the software realm). Clearly, open source development would also facilitate commonality in space system design through accessibility and reuse of design documentation and test / operations procedures.

- Contribution towards FTD Goal 3 (leverage development and investments made by partners); open source engineering projects, whether aimed at the entire mission architecture / concept or at specific subsystem or component design aspects could result in significant leverage of investments (in terms of work-time) provided by qualified individuals through open source design and / or prototype building and testing. The qualified individuals could be in industry, government, academia. It is particularly the latter categories of potential contributors that are already to date engaged in significant research and pre-development activities relevant to FTD missions; however, these ongoing efforts are not coordinated and oftentimes result in duplication of effort.
- Contribution towards FTD Goal 4 (educate and inspire): open source space development communities and projects would clearly have a high potential for attracting and involving educators, students, as well as the general public (as represented in the open source space development community) in NASA's exploration enterprise.
- Contribution towards FTD Technology Goals and Objectives: open source engineering projects based on a community of aerospace professionals and students could clearly make significant contributions towards affordable design, development, as well as ground-based testing of all the technologies outlined in the FTD RFI. As mentioned above, efforts with regard to design, development, and testing of related technologies are already underway at many academic institutions across the US and the world.

DevelopSpace Initiative, Inc.

While some open source space-related endeavors have occurred to date, having an organization dedicated to promoting and providing the infrastructure for such activities will be quite beneficial. The overall goal of DevelopSpace is to build-up the technical foundations for human space activities, by doing just that. 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 intends to 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, including in ways which contribute to NASA's exploration enterprise and the FTD missions.

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. 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.

DevelopSpace is open to engaging with NASA to further develop means by which open source development methodologies can be integrated into the Flagship Technology Demonstration program, in order to increase the efficiency and effectiveness of the program, and speed the adoption of the demonstrated technologies more broadly.

For a discussion of additional ways in which DevelopSpace could also support the efforts of NASA's participatory exploration program through the creation and development of an open source community dedicated to exploration and human expansion into space, please refer to our response to Section 10 of this RFI.