



Limitless Space Institute Interstellar Initiative Grants Request for Proposals

Solicitation Number LSI-I2G-2020-01 *†‡§||¶**††

* 1 May 2020: Solicitation Release Date

† 1 May - 14 May 2020: Receive e-mail questions

‡ 15 May 2020: Publish Q&A Addendum

§ 1 June 2020: Preproposals Due (Phase I)

|| 15 June 2020: Full Proposal Invitations

¶ 15 July Full Proposals Due (Phase II) (15 pages)

** 1 Sept 2020: Award Announcements

†† Submit proposals in electronic (pdf) form to: jan@limitlesspspace.org

Executive Summary

Human exploration of the outer solar system and on to the stars will require significant advances beyond the performance characteristics currently representative of state of the art for spacecraft power and propulsion systems. However, due to the low maturity and high risk associated with the nascent engineering and physics concepts discussed in the literature, there is a severe lack of dedicated support for this type of advanced research and development across academia, industry, and government. As such, the Limitless Space Institute is initiating a research grant initiative with the goal of providing measured and consistent support for pursuing interstellar research called *Interstellar Initiative Grants*. This call for proposals is seeking grants that can be categorized as either a *tactical grant* ($\leq \$100k$) or a *strategic grant* ($\leq \$250k$), with the former focused on theoretical and the latter on empirical. The period of performance for the grants is expected to be ~12-14 months duration, with a potential start date just before the beginning of the 2020 academic fall semester. It is LSI's vision that by establishing the *Interstellar Initiative Grants*, and by conducting these grant awards on a biennial cycle, LSI will help grow and mature the capabilities of the interstellar research community. LSI hopes that supporting this domain in this sustained and tangible financial manner will inspire and educate the next generation to pursue the research and development of enabling technologies to one day allow for interstellar human space exploration.

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1 Background

Human exploration of the outer solar system and on to the stars will require significant advances beyond the performance characteristics currently representative of state of the art for spacecraft power and propulsion systems. In some cases, the magnitude of these performance improvements will likely require new understandings of physics prior to engaging in any engineering development. For the concepts that *are* based on well established physics¹, a number of things have impeded meaningful progress towards flight applications. The technology readiness levels (TRL) for nearly all of these concepts are much less than three, making it highly improbable that commercial aerospace companies will spend internal R&D monies to explore these high-risk endeavors, and equally unlikely that government authorities will allocate precious municipal funds on R&D with no immediate mission pull/application². Additionally, in some scenarios, working to develop some of these concepts necessarily deals with high energy radiation necessitating regulatory oversight, which further complicates the development activities. Since there are no existentially critical “mission-pull” architectural needs from government or industry that overcome all obstacles and objections to investment in developing these concepts, they go neglected *ad infinitum*.

For the concepts that require new understandings of theoretical physics and physics foundations, academia is an ideal community to take a leadership role in exploring the efficacy and viability of these novel (and sometimes speculative) approaches. In order for academia to be adequately represented in the endeavor of developing revolutionary power and propulsion concepts to enable bold exploration of the outer solar system and the stars, there has to be a sponsor organization to facilitate research funding for lab work, theoretical work, publication costs for journal articles, collaboration with peers at conferences, and student costs. Professors, in their quest to obtain tenure at their host university and home department, recognize that the coin of the realm is that they must publish citable papers in peer review journals, and win research dollars for the university. As it stands, there is no governing organization, public or private, that actively, adequately, and consistently funds research and development of breakthrough propulsion and power concepts relevant to enabling interstellar flight.

To explore and develop this high-risk domain, there needs to be an organization wholly and singularly com-

mitted to pursuing *and funding* the research and development activities necessary make meaningful progress towards one day achieve the long-term goal of bold human exploration of the outer solar system and out to the stars.

2 Interstellar Initiative Grants

The Limitless Space Institute (LSI) is a non-profit organization, established in 2019, whose vision statement is to advance human exploration beyond our solar system. The heart and soul of the institute is research and development activities, as that is the critical work necessary to enable the pinnacle objective of achieving interstellar human space exploration. This hyper focus on *doing* and *funding* applied R&D emerging from the frontiers of physics and engineering as they pertain to interstellar flight will attract top scientists and engineers from around the world to partner with the institute in the pursuit of this vision and be challenged to greatness. As part of the institute’s inauguration, LSI is offering a series of research grants through the Interstellar Initiative Grants (I² Grants) program.

It is envisioned that funded grants will take the form of either a theoretically-focused grant dubbed an *Interstellar Initiative Tactical Grant*, or an empirically-focused grant called an *Interstellar Initiative Strategic Grant*³. In both scenarios, partnering will be encouraged, and engaging with academia to a degree will be a requirement. Cost-sharing of grant execution will be given weight in the proposal review process to encourage proposers to seek resources from their home institutions/organizations to ideally increase the gear ratio of the resources LSI is committing to the endeavor.

Tactical grant awards, being predominantly academic exercises not requiring the design, fabrication, calibration, and operation of customized laboratory equipment are expected to be ≤\$100k for a 12-14 month award. A body of work for a tactical grant might entail derivation or development of a physics model exploring the efficacy and implications of an idea towards achieving the pinnacle objective of starflight. This process may also incorporate detailed computer analysis by custom or commercial software to explore and evaluate performance characteristics of concepts based on these nascent theoretical models. While performance characteristics for mission applications are useful to gauge if an idea is enabling or competitive, care must be taken to not sub-

¹high-power in-space nuclear reactors, high-power electric propulsion systems, fusion power, and fusion propulsion to name but a few

²While academia has the occasional participant, usually culminating in the form of theoretical physics journal papers, without consistent external funding from either industry or government, academia is unlikely to be motivated properly fill the gap as it were.

³In this case, the reasoning behind categorizing theoretical as tactical is that it seems analogous to taking a hill in a military conflict - by itself it will not win the war, but is a necessary step to do so. Meanwhile, making the giant leap of actually conducting a laboratory test to collect “existence proof” of a nascent idea in physics or engineering has the potential to realize a paradigm shift - hence the strategic classification.

mit a proposal focused on the optimization of a nascent concept when empirical existence proof of a speculative concept is paramount and of primary importance⁴.

Strategic grant awards are the laboratory focus of the initiative, and will necessarily require more resources to cover the cost of conducting laboratory activities. Similar to the tactical grant, these strategic awards will incorporate theoretical elements based on emerging physics models that have been shown either in the literature or by the proposer to predict observable results in a laboratory setting. The strategic grants are expected to be $\leq \$250k$ for a 12-14 month award. A notional strategic grant based on known physics might propose an experiment to produce a production superconducting coil capable of achieving a peak field strength of 30 Tesla which might have the potential to shrink a magnetically confined fusion reactor to a size compatible with heavy lift launch capabilities. The work would not produce a fusion reactor, but it would pursue an aspect that has the potential to both hasten terrestrial development and identify a path for migration to flight. A notional strategic grant based on nascent physics might propose the manufacture and testing of tapered Casimir cavities to determine if there is structure in the quantum vacuum as predicted by the dynamic vacuum model[1]. While this experiment might appear to be purely scientific in nature, if there is structure to the vacuum, this would have implications on whether one can push off of the vacuum, extract energy from it, or utilize it in some to-be-determined way to yield wormhole or space-warp physics in the lab.

Grant teams should incorporate university participation such that $\sim 1/4$ of the resources are committed to the academic partner(s). Further, the tactical grants should facilitate the cost of at least one student (intern or research assistant) being involved in grant execution, and strategic grants should cover the cost of having at least two students engaged in grant execution. Grants should seek to publish at least one paper in the peer-reviewed literature discussing the work at length, and Principal Investigators (PI) are expected to give a detailed technical presentation at the final, semi-public workshop at the close of the biennial grant cycle.

2.1 Project Areas to be Funded

With the pinnacle objective of enabling human exploration beyond our solar system and on to the stars, due to the physics involved, the single most important performance metric is the ability to GO INCREDIBLY FAST to any destination. Technologies proposed to be matured and physics concepts proposed to be explored should

⁴In other words, proposers must refrain from overly focusing on things like the layout of the bridge controls on the *Enterprise* when nobody knows how to even build a basic warp engine, or if it is even possible.

invariably trace to this performance guideline. While there are a large number of possible reference materials that could be used to detail the scope of interest for the grant solicitation, a select handful are briefly detailed here for calibration purposes. Firmly within the realm of known physics, McNutt [2] published a thorough paper detailing the nuclear electric propulsion performance requirements to support human exploration of the outer solar system. This manuscript shows the importance of propulsion systems coupled to persistent power sources (nuclear reactor) that have specific impulse values that fall in the thousands of seconds range. The NASA Technology Roadmaps [3], specifically TA 2.3 Advanced Propulsion Technologies and TA 3.1 Power Generation⁵ enumerate a list of candidate technologies and topics relevant to the stated objective ranging from fusion power to breakthrough propulsion. Another useful and recognized reference is the book titled *The Starflight Handbook*[4] which is a compendium of many and varied techniques that could be used to cross interstellar distances such as nuclear pulse propulsion, solar sails, beamed energy propulsion, fusion ramjets, and wormholes in spacetime (to name a few). The book titled *Frontiers of Propulsion Science*[5] explores concepts that fall on the leading edge of our understanding of physics, and numerous chapters explore current thinking on topics ranging from space drives, thrusting against the vacuum, space warps, and wormholes. For a more focused technical expansion on the concept of space warps and wormholes, the recently published book titled *Wormholes, Warp Drives and Energy Conditions*[6] provides a thorough treatment of the subject.

The focus of submitted proposals should be clearly traceable to the pinnacle objective of enabling bold human exploration of the outer solar system and one day on to the stars. Further, the scope of the proposed work should, upon grant completion, show measurable progress towards in advancing our understanding of the competitiveness, viability, and/or efficacy of the particular approach being investigated.

2.2 Information for Proposal Teams

Limitless Space Institute (LSI) is initiating a series of research grants with a purely theoretical emphasis (*tactical grant*) and with an empirical focus (*strategic grant*), each geared towards making meaningful progress towards the goal of exploring the stars. The period of performance for both classes of grants is expected to be a 12-14 month period of performance. As indicated earlier, the *tactical grants* are expected to be $\leq \$100k$, and the *strategic*

⁵While NASA has migrated the content from the 2015 technology roadmaps to a “technology taxonomy” format in 2020, the original roadmaps contain some details that will not be found in the newer taxonomy format.

grants are expected to be $\leq \$250k$. Since this is an inaugural solicitation, any proposal team that seeks to win a *strategic grant*, not having executed a *tactical grant*, will need to clearly demonstrate a high level of maturity of their concept/approach by providing ample evidence of materials published in the peer-reviewed literature. LSI anticipates an inaugural class consisting of approximately 4-10 tactical grants, and possibly 1-2 strategic grants, depending on the quality and strength of submitted proposals. Additionally, LSI may opt to add, at its discretion, additional smaller awards for shorter ~ 6 -month studies after the period of performance for the grants has already begun, based on high quality submissions.

Costs associated with grant execution should not cover Principle Investigator/Professor salary, as it is envisioned that these costs should be covered by the home organization for the PI/Professor as a measure of cost sharing for the execution of the work. Grant costs should be reserved for student costs, computational needs, procurement of software and lab equipment, engineering development costs, contract design and fabrication, and some amount of operational costs for scientific facilities if warranted. Cost sharing is fully expected to be reflected in the proposal write up, and this will be heavily considered during the review process. Although the grant classes have associated cost caps, each grant proposal should only seek the resources necessary to pursue the targeted work, and care should be taken to develop a cost proposal that is clearly not just tied to the cost cap.

As discussed earlier, grant teams should incorporate university participation such that $\sim 1/4$ of the resources are committed to the academic partner(s). Further, the tactical grants should facilitate the cost of at least one student (intern or research assistant) being involved in grant execution, and strategic grants should cover the cost of having at least two students engaged in grant execution. Grants should seek to publish at least one paper in the peer-reviewed literature discussing the work at length, and Principal Investigators (PI) are expected to give a detailed technical presentation at the final, semi-public workshop at the close of the biennial grant cycle.

Grant awards will require the PI support a Grants Kick-off meeting in late August 2020, a Grants Midterm meeting in late January 2021, and a final Grants Symposium meeting in late September 2021⁶. The Kickoff meeting will consist of a day-long meeting where each Grant performer will provide an overview of the proposed work to be completed, and answer a few questions from key audience participants. The Midterm meeting will consist of approximately a day and a half of detailed techni-

cal presentations, discussion periods, and sidebars. For the final grant workshop, it is anticipated that this will be done in partnership with the biennial Foundations of Interstellar Studies Workshop⁷ where there will be an additional day added to this workshop for the grant performers to give final technical presentations to LSI representatives and a select cross section of the technical interstellar community comprising of individuals from industry, academia, and government.

2.2.1 Collaborations



The Breakthrough Initiatives organization has graciously agreed to cover the travel costs for PI participation, venue arrangement, and live webcasts for the Kickoff, Midterm, and Symposium meetings. LSI expresses its deep gratitude to the Breakthrough Initiatives team for leaning in with LSI in this way to help improve the public engagement of LSI's Interstellar Initiative Grants effort.



Texas A&M University has graciously agreed to serve in the role of contract administration and enforcement for the grants, and will serve as the funding conduit through which LSI will administer the grant funds. LSI greatly appreciates Texas A&M University's willingness to serve in this capacity for this endeavor.

⁶If current events preclude the option of holding one or more of these meetings as a face-to-face meeting, accommodations will be made to host the meetings virtually to allow for remote participation and for progress to continue. *Fortitudo per aspera*.

⁷FISW held two prior workshops, one at City University of New York[7] in 2017, and a second in the UK[8] in 2019. These workshops consisted of three days of technical presentations covering interstellar flight topics that range from solar sails to wormholes to government policy.

2.2.2 Eligibility

All (non-government) responsible sources capable of satisfying LSI's stated research objectives may submit a proposal that will be considered by LSI. Non-U.S. organizations and/or individuals may participate to the extent that such participants comply with any necessary nondisclosure agreements, security regulations, export control laws, and other governing statutes applicable under the circumstances.

2.2.3 Proposal Dates

The submission process will consist of two phases:

- Phase I - the first phase seeks preproposals from investigators that will be reviewed, and a subset of the preproposal candidates will be invited to submit a full length proposal,
- Phase II - the second phase is by invitation only, and invited proposers from the preproposal phase will be asked to submit a longer, more detailed proposal.

The key milestones for this inaugural grant cycle are as follows:

- 1 May 2020: Solicitation Release Date
- 1 May - 14 May 2020: Receive e-mail questions
- 15 May 2020: Publish Q&A Addendum
- 1 June 2020: Preproposals Due (Phase I) (3 pages)
- 15 June 2020: Full Proposal Invitations
- 15 July Full Proposals Due (Phase II) (15 pages)
- 1 Sept 2020: Award Announcements, Selected Teams begin 12-14 month Period of Performance based on contract negotiations
 - Performer Kickoff Meeting, date TBA
 - 6-month face to face review, date TBA
 - present grant findings at semi-public biennial conference, date TBA

2.2.4 Phase I Proposal Submission Guidelines

Phase I Preproposals should contain the following information, and should be limited to three 8.5" x 11" pages, 12-point font minimum:

- **Abstract** of proposed work and objectives
- **Cost and Schedule Summary** (highlight cost sharing and academic partnerships)
- **Key References** (optional - does not count towards three page limit)

Abstract Provide an abstract summary of the proposed work. Identify the critical tasks and technical risks. How does this work make measured progress for the idea/concept? Explain how the work traces to the

pinnacle objective of one day enabling human exploration of the solar system and on to the stars. What team members will be performing the work, and what facilities, software, and/or assets will be utilized during the pursuit of the work.

Cost and Schedule Summary Provide a summary of the estimated total costs for the proposed body of work. Break down this total cost into labor, materials, procurement, software, tuition, consultant costs, and travel cost.

Key References Provide supporting references for the preproposal write up. This section does not count against the three page limit.

2.2.5 Phase II Proposal Submission Guidelines

Phase II Full Proposals should contain the following information, and should be limited to fifteen 8.5" x 11" pages, 12-point font minimum:

- **Executive Summary** of proposed work and objectives
- **Technical Plan**
- **Capabilities/Management Plan**
- **Detailed Budget**
- **References** (optional - does not count towards fifteen page limit)
- **Appendix** (optional - does not count towards fifteen page limit, but may not be considered as part of review process)

Executive Summary This section should provide a concise overview of the proposed work. Some key questions to be addressed while crafting this narrative are provided here:

- What is the proposed work attempting to accomplish?
- How does this work relate to the pinnacle objective of enabling human exploration of the outer solar system and the stars?
- What are the critical technical challenges?
- How much will this work cost?

Technical Plan Detail the plan (statement of work, tasks, schedule) to achieve the proposed work. Provide a detailed task breakdown and related milestones. Provide a schedule showing the key milestones, tasks, and the interrelationships among the tasks.

Capabilities/Management Plan Provide a summary of the proposed team members, describe how their skills pertain to the proposed work, and identify roles and responsibilities (identify the principal investigator (PI) for the project). Highlight key facilities, software/computational assets that will be utilized in the execution of the proposed work plan. Explain the proposed management approach for the team and reportability to LSI on grant execution progress.

Detailed Budget Provide the following costs details: direct labor (can include indirect costs), materials, equipment purchases, software purchases, tuition, consultant costs, and travel on a monthly basis. Travel costs need not cover travel for PI for the three Grant meetings (Grants Kickoff, Grants Midterm, and Symposium) as these costs will be covered by the Breakthrough Initiatives organization. Itemize and provide quotes for single procurement (materials and equipment) items that exceed \$5000. Proposers should identify and highlight cost sharing aspects of proposal budget.

References(optional) Provide supporting references for the proposal write up. This section does not count against the fifteen page limit.

Appendix(optional) It is optional for a proposal team to include supporting technical materials in an appendix, however it must be noted that this material might not be utilized during the review process. Care must be taken to not include critical material in the Appendix.

2.2.6 Proposal Review

The Proposal review process will engage a team of external cognizant personnel (consisting of at least one representative from the Breakthrough Initiatives team) to aid the LSI Director of Advanced R&D to review and rate compliant submitted proposals. Some proposers may be asked to support phone interviews to help aid the LSI team in making award down-select decisions. Some proposers may be asked to evaluate de-scoping options. The review team and the LSI Director of Advanced R&D will make final funding recommendations to the LSI Chairman of the Board and the LSI President. Ultimately, the final award decision authority for awardees rests with LSI, and LSI will select the proposals that provide the best value to the institute and LSI's pinnacle objective. The review criteria that will be used to evaluate the individual submissions are as follows:

- Alignment - how well does the proposed work align with making meaningful progress towards enabling bold human exploration of the outer solar system and out to the stars?
- Value Proposition - does the proposed work show strong potential benefit to either maturing a concept, or rigorously evaluating a foundation of physics concept?
- Strength of Team - is the team comprised of individuals with a documented history in the literature already working towards the stated proposal objectives, and are the facilities (labs and/or computational assets) sufficient to accomplish the stated work? Does the team incorporate academic partnerships?

- Price/Cost - are the proposed costs reasonable and believable? Does the proposal incorporate effective cost sharing with proposer home organization?

2.2.7 Proposal Contracting and Reportability

Selected proposals will enter into a contractual agreement between the PI's home organization and LSI. As LSI is a 501(c)(3) non-profit organization, the intention is for all work performed as part of grant award and execution to be made fully available to the public. If there are proprietary matters⁸, or export control, it is the responsibility of the proposal team, namely the PI to notify LSI prior to contract award and execution so that an appropriate disposition can be determined that will be acceptable to both parties. The Grant team will be expected to support monthly tag-ups (with briefing materials) with salient LSI personnel to provide updates on grant execution status. The PI of the Grant team is expected to support one face-to-face meeting (tentatively in Houston, TX) meeting at the midpoint of grant execution to provide a more detailed account of progress to date. The PI of the Grant team is also expected to give a detailed close-out technical presentation at the final, semi-public workshop at the close of the biennial grant cycle. The Grant team will provide a final written report (and supporting data/authored software) to LSI as the final delivery products at Grant conclusion. The Grant team is also highly encouraged to plan on submitting a paper for peer-review after completion of the grant execution.

3 Relevance

What are the benefits of undertaking the process of implementing the competitive *Interstellar Initiative Grants*? As indicated in Section 1, there are really no dedicated and consistent funding sources from government, academia, industry, or non-profit organizations seeking to regularly sponsor the type of research necessary to enable bold human exploration of the solar system and the stars. While there may be an occasional call for fundamental science research from a government agency that has enough overlap with a starflight-related frontier of physics such that a savvy PI can secure a grant, these opportunities are few and far between leaving an austere interstellar research climate. This has the net effect of precluding the development of a robust and mature community of researchers whose declared purpose is to solely pursue revolutionary power and propulsion physics for spaceflight.

⁸It is LSI's expectation that in the event of development of Intellectual Property (IP) as a result of the grant execution process, LSI will be granted complimentary royalty-free license access to the noted IP.

By establishing the *Interstellar Initiative Grants*, LSI will help grow the capabilities of the interstellar research community. Individuals in academia who are interested in working in this domain would, upon successfully winning a grant, be able to shift from a mode of avocation to vocation with the award providing the means and motivation to pursue research - all the while satisfying university requirements to win research grants and publish papers⁹. Individuals from industry or the private sector may be able to use the grant initiative to secure some measure of matching funds from their home organization in the event of winning a grant award that would have otherwise not been allocated to this high-risk endeavor, giving LSI a better gear ratio on grant resources. Similarly, individuals from government could use the grant initiative to convince their home organizations that it is worthwhile to facilitate and possibly even co-sponsor interstellar research in their facilities. Having a regular biennial grant call for proposals will help mature the community at large and possibly encourage other organizations to either collaborate with LSI to expand funding scope, or to initiate their own interstellar research grant program.

4 Concluding Thoughts

This solicitation has identified the severe lack of dedicated and consistent support for advanced research and development of science and engineering related to human exploration of the outer solar system and on to the stars. A research grant approach has been detailed herein, both in scope and scale, to help address and overcome a number of the current obstacles to consistently pursuing interstellar research as a vocation. Forthwith, LSI is pleased to be able to initiate this inaugural instantiation of the *Interstellar Initiative Grants* with a target start date for performers to occur close to the beginning of the 2020 college fall session. The institute looks forward to working with the deep space exploration community in the coming months during the proposal submission and review process, and is looking forward to witnessing the meaningful progress that will be made by performers as a consequence of grant execution. LSI hopes that through the award and execution of these grants to establish deeper contacts and build stronger relationships with the broader technical community. Further, supporting this domain in this tangible financial manner will serve inspire and educate the next generation to pursue the research and development of enabling technologies to one day allow for interstellar human space exploration (see Figure 1).

⁹The coin of the realm of the academic world is “publish or perish” and win research grants.



Figure 1: *IXS Enterprise en route to interstellar destination*¹⁰.

Godspeed!

References

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¹⁰The IXS Enterprise concept was an education outreach concept based on work of the primary author published in the literature[9]. Matt Jefferies, the creator of the familiar *USS Enterprise* from the television show *Star Trek* had an earlier starship concept called the *XCV Enterprise* that was nearly correct based on the math explored by White. White worked with Mike Okuda of CBS and Mark Rademaker to update the *XCV Enterprise* concept to more properly reflect what is required from the math and physics. The result was the *IXS Enterprise* concept which was incorporated in to the 2014 *Star Trek Ships of the Line* calendar[10].

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