



**Lightweight Geospatial Database for Subterranean, Terrestrial, Orbital, and Deep Space Deployment**

**Project Pitch: 00005603**

**SBIR/STTR Topic Area: SBIR: Space (SP)**

**Prepared by Ian Gerard, Adder Mobile Technologies, Inc.**

No other federal agencies have received this proposal.

## **1. Project Summary**

### **Overview**

Some of the most substantial difficulties for geospatial information systems professionals arise from exponential increases in sensor data now being collected by smartphones and IoT devices. Trillions of data points are generated, daily. The challenges in making this data useful are immense.

Cloud service providers, such as AWS, Azure, and IBM Softlayer, have not yet made any clear efforts in creating a databasing system optimized for geospatial read and write operations. This creates an immense processing, memory, and storage burden for anyone working with large GIS datasets.

Efficient and rapidly queryable geospatial database operations for GIS systems continue to challenge researchers, data analysts, and software developers. Geospatial data processing and storage needs continue to grow rapidly as new requirements are created, predominantly in fields pertaining to transportation, information, and communications technology.

Numerous scientific and commercial ventures would benefit greatly from optimized and rapidly deployable databasing systems that are designed to facilitate geospatial data sharing and integration of many disparate datasets.

This proposal focuses on creating a GIS database system purpose-built for high speed geospatial data ingest and ease of database deployment, allowing flexibility for numerous geospatial data handling applications.

Specifically, our goal is to simplify geospatial data handling and processing operations in order to facilitate meta-scale machine learning operations to uncover deep insight about human behavior and physical locations.

### **Key Words**

Geospatial Information Systems (GIS), Sensor Data, Cartography, Non-relational Databasing, Global Positioning System (GPS), Parallel Processing, Deep Learning, Image Processing

### **Subtopic Name:**

SP2. Geological and Geoclimatic Science Data Products and Services

### **Box 2: Intellectual Merit:**

This Small Business Innovation Research Phase I project will apply new technologies in novel processes to facilitate the efficient storage and retrieval of geospatial data collected or otherwise sourced by sensors deployed in both large-scale terranean, subterranean, and space based environments.

This problem must be addressed in order to effectively catalog and track space-based vehicles, habitats, sensors, debris, resources, points of interest, and other relevant spatial data on low-power, autonomous systems. Substantial issues -- such as efficient indexing, millions of document insert operations per

second (IOPS) and transmission to compute and memory/storage nodes will need to be addressed during this project.

Our technical plan, broadly, is to maintain a lightweight structure that utilizes high bandwidth memory hardware to distribute memory intensive indexing workloads without requiring high TDP CPUs. These workloads will be processed in parallel, leveraging recent advancements in HPC and ASIC technology.

Additionally, 'intuitive indexing' of geospatial data will play a critical role in accomplishing our goals. This concept is based on decreasing index size by using a 'baked-in' geospatial framework to identify and label data.

**Box 3: Broader/Commercial Impact:**

Outcomes of this phase I project will include a ready to market solution for in-field data collection, storage, and processing for vehicles and city data. semi-autonomous space-based satellite configurations.

Specifically, we will be able to assist in simplifying and derisking high impact, high risk data science projects. This databasing system is eventually intended to facilitate the cataloguing and tracking of space-based resources that will be critical for future economic activity beyond Earth.

The broad economic impacts of such a project are numerous, but we believe this effort is vital to facilitate the creation of space based cartography, navigation, and analysis standards.

This will not just affect Earth based interests, but rather, such a project could have a substantial and positive impact on the advancement of the human civilization to becoming a multi-planet species.

**3. Project Description. [Fifteen (15) pages MAXIMUM].**

***The Customer***

Location based commercial interests have expanded dramatically over the past decade, increasing the demand for geospatial databasing structures for myriad environments, on Earth and beyond. Cubesat and other small satellite systems have become ubiquitous within the scientific community, and represent a new internet of thing -- all collecting and transmitting valuable data critical to the future of human development as we reach further into the cosmos.

Space-based commercialization efforts, as a result, have expanded to include a number of new value propositions, and these will all require foundational systems to serve as the backbone for future space-based development. Specifically, navigation and mapping tools will be needed by the majority of space-based commercial interests.

The capacity of the NASA DSN to receive transmitted data precludes the ground based processing of petabytes of geospatial data sourced from swarms of probes. This problem will become increasingly substantial with the advent of low cost to orbit payload delivery systems from Space X, Blue Origin, Sierra Nevada, Vector Launch, and others.

Our proposal will address the underlying database systems needed by space technology companies and

researchers to efficiently collect, store, and process geospatial data gathered in large scale terrestrial and space-based environments.

Such a databasing system will address needs across many space based industries, including but not limited to resource identification, extraction, zero-g manufacturing, solar and extrasolar mapping, threat identification, debris monitoring and removal, and other developing zero-g industries.

We intend to create a location tracking SDK that satisfies their needs while also working to help developers and other app makers that could use an easier mapping solution.

## The Value Proposition

*What are the benefits to the customer of your proposed innovation?*

At the time of writing, there is no clear solution to database disparate geospatial data sets without custom tailored solutions.

For the past several decades, spreadsheets and elbow grease have been the preferred tools of statisticians in this field, however, as data collection increases exponentially, new problems arise.

A system that could solve this challenge would be highly beneficial for many public and private research and development efforts focused on big data and space based data collection, storage, and processing.

Goals for the initial stage of this project would be to create an easily containerized database solution designed to assist in implementation of GIS deployment at any scale.

Additionally, an established network of space based processing systems, interlinked, utilizing this database could be used for cloud services solutions to space based processing tasks, eliminating the cumbersome process of communicating via DSN to ground-based processing clusters. This system would be useful for many companies with our own pre-existing configurations deployed in orbital environments. This would effectively serve as a deep-space cloud processing and databasing system in the long term, and this is one of our overall goals in pursuing this technology research project.

Imagining a competitive context, our solution will provide customers value by decreasing their time training staff, organizing database structures, and implementing a solution to sensor data collection and processing for distributed systems. This system could also introduce a unified architecture for adding additional capabilities via integrations from third party developers.

This proposed swarm-database architecture could also potentially reduce the time needed to send verified data packets back to ground stations, transmitting from node to node rapidly, drastically reducing onboard memory needs during data packet transmission.

1. Tagging and tracking of high-importance assets and natural resources, such as asteroids, will prove invaluable for future space based corporations.
2. Less time spent designing, inserting, and maintaining this database = cost savings
3. Fewer operational staff needed = cost savings

*What is the key differentiator of your company or technology?*

Relational spatial databases have existed for decades, with lifetimes of expertise invested into the challenges of terrestrial databasing. The standards comprising the private-sector “State of the Art” are well established, and offer many resources that cannot be accomplished with Open Source developers. We are aware of many GIS platforms that operate well in terrestrial capacities, which is why we do not seek to disrupt the spatial database environment here on Earth in the traditional capacity.

Instead, we intend to fill a gap in the space-based data processing market.

Future space exploration and expansion will require humans to innovate on communication within and analysis of our solar system. To do this, we will be taking the innovative, state-of-the-art spatial databases that work well here on Earth and rebuild them to work on hardware that can fit within NASA’s CubeSat specifications. These satellites will be able to distribute processing and storage of data not only of earth, but of other places in our solar system wherever a cluster is deployed. Instead of deploying a cluster within a location on Earth, we can deploy clusters within space around different planets or objects inside our solar system. This proves to be valuable because we no longer need to transmit all of the raw data to Earth. The data can be stored and processed on these satellites, and whenever someone wants to observe what’s going on, a query can be sent to and executed on one of the satellites within the cluster.

*What is the potential societal value of your innovation?*

- Creation of autonomously generated maps and other geospatial data collection will be streamlined by this innovation, as a standardized databasing and processing system will reduce the need to clean and translate data sets.

*The Innovation:*

Succinctly describe your innovation. This section can contain proprietary information that could not be discussed in the Project Summary. What aspects are original, unusual, novel, disruptive, or transformative compared to the current state of the art?

- Spatial database designed to store petabytes or terabytes of data per day as well as a spatial analysis engine that is designed to run on CubeSats (or within the database itself). These types of databases and analysis engines are nothing new, but designing them to work on systems that can fit in CubeSats is going to be the unique offering that our

***The Commercial Opportunity (recommended length: 2-4 pages)***

This database will be used for many purposes, and societal needs are a substantial part of our driving motivation to create this system.

While the purpose of this proposal is to create a databasing system that will benefit our own existing commercial efforts, as well as future endeavors, we see a public value as well.

The public benefits we've identified can be broken into these categories:

1. Military Logistics Analysis and Management
2. Orbital Debris Tracking and & Navigation
3. Planetary Observation & Autonomous Cartography
4. City Scale Infrastructure Management & Planning
5. Traffic Monitoring and Management
6. Crime Reduction
7. Geophysical Data Processing (Geology, Meteorology, Hydrology, etc)

#### Military Logistics Analysis and Management

##### Orbital Debris Tracking

Perhaps the greatest threat to human infrastructure and expansion is the increasing amount of debris orbiting around Earth. Coupled with the advent of new 'satellite-killing' rockets, the potential for this to occur is expected to compound dramatically.

While not the primary focus of this project, it is nonetheless relevant to address the need to mitigate risks, where possible, to our current GPS and communications satellite constellations.

The Kessler Effect is a type of chain reaction known as an ablation cascade. In an ablation cascade event, debris strikes an intact satellite, fragmenting debris in unpredictable directions. This newly fragmented debris can strike additional satellites, leading to an exponential increase in ablative debris strikes.

A substantial ablation cascade in orbit would be catastrophic for terrestrial communications and geolocation services. Many lives could be lost, but the threat to infrastructure will be substantial if steps are not taken to mitigate the risks of orbital debris.

The proposed databasing system could be optimized to track and process data gathered from a Cubesat swarm, and this would be the initial intended purpose in space commercialization. This system, therefore, could save public and private entities millions to billions of dollars, and help prevent multi-trillion dollar catastrophes by applying predictive location analytics developed by Adder.

#### Autonomous Cartography

The intended long term functions of this database platform are intended for use in deep space navigation and cartography. These tasks will require a system that can parallelize geospatial processing tasks in a mesh-like network running on data collection Cubesats.

### Smart Cities & Infrastructure Planning

One unique set of use cases brought to us has been that of infrastructure planning by large metropolitan governments. The initial test use case, for Louisville, Kentucky, focus

### Geophysical Data Processing

### Emergency Location Services

In the case of smart cities, movement data is the core of every decision making apparatus, with many disparate types of devices reporting data that can, generally, be tagged to a specific location. Our initial discussions about solving problems with smart city data started with the City of Louisville, Kentucky, when they were having issues utilizing Amazon Web Services (AWS) to process massive amounts of movement data. We've already solved the specific problem they were dealing with by

*Describe the market and addressable market for the innovation. Discuss the business economics and market drivers in the target industry.*

The space exploration market is being driven primarily by companies that need satellites lifted into orbit, and the services surrounding this market.

Recent data shows a rapid expansion trend in these areas, however, the launch vehicle market itself is saturated at the moment. Instead, our immediate go-to-market focus will be in orbital cloud data processing and object tracking to prevent and mitigate orbital collision events.

*How has the market opportunity been validated?*

This market opportunity has been validated by our own needs as a geospatial analytics provider, as we have already monetized cloud services in this field previously. Now, we are setting our sights toward the next series of challenges, and we are committed to the goal of developing this system for our own autonomous mapping needs, and to solve numerous other mapping challenges.

In 2018, over 200 billion dollars were spent globally on positioning and mapping services, and this number is expected to increase dramatically as the internet of things grows at an exponential rate.

This insight has led us to the conclusion that such a system is not just desired by niche markets, it is necessary to facilitate the future geospatial data economy.

*Describe your customers and your basic business model. Describe the competition.*

*How do you expect the competitive landscape may change by the time your product/service enters the market?*

We expect to secure our place as a thought leader in the geospatial analytics industry before this product is marketable, and thus, we will be perfectly positioned to introduce a paradigm-shift in databasing technology for distributed systems.

At present, we already have strategic partnerships in place with Comcast, NBC, and Universal Studios to monetize our services. We believe that our relationships with Fortune 100 companies will serve as a validating mechanism and a springboard for our company to further expand into new markets.

We are also beginning discussions with enterprise services providers in the data processing market, specifically, Fujitsu, to explore monetization and commercialization of the innovation.

***What are the key risks in bringing your innovation to market?***

Acceptance and adoption are, generally speaking, the most difficult aspects of launching a new backend services solution, particularly with respect to databases.

Making the jump from one widely accepted platform to an unknown, unproven system will prove challenging for developers that have not been exposed to our GIS methodologies and code base. This means that education will be a necessity, requiring that robust documentation of the proposed system be generated.

Perhaps the greatest risk to this project is IP protection, as we could be outpaced by a large enterprise in funding capacity, however, we have not had any issue with this in the past. Generally, compartmentalization has been a key approach to ensure security of our trade secrets and customer data. We have an experienced team of patent attorneys that will be instrumental in the long term protection and licensing of the proposed technology.

***Describe your commercialization approach.***

Our commercialization approach for this database invests substantially up-front on R&D, as is the case with many foundational software innovations. Our intention is to build with intent to replace the current databases we use, which will provide a number of long term benefits to the establishment of Adder's geospatial cloud services.

Pending SBIR funding from NSF and subsequent matching funds from the Kentucky Innovation Network, we have already invested our own capital over time into these goals. We are also seeking corporate R&D partnerships with large enterprise service providers and hardware manufacturers to assist in the pre-revenue stages of development. We've met with Fujitsu, IBM, Comcast, and a handful of other major service providers that would be interested in testing our system, when completed.

Early deployments of this databasing system will be leased directly to the Adder Mobile Technologies, Inc. Geospatial Analytics Division, generating immediate revenue by replacing the current solutions utilized in those efforts.

The long term commercialization will consist of a traditional model of free and discounted usage tiers to aid in developer adoption, which will also aid the feature discovery process. Larger enterprise customers requiring plug-and-play integrations and cloud services will provide the long term revenue needed to grow the cloud services further, expanding the range of data collected.

***Discuss the potential economic benefits associated with your innovation, and provide estimates of the revenue potential, detailing your underlying assumptions.***

If completed for use by 2021, Adder is projected to generate over \$1.1 million in revenues using this system, serving as a useful case study and proof of concept for others to adopt.

***Describe the resources you expect will be needed to implement your commercialization approach.***

*Describe your plan and expected timeline to secure these resources.*

In order to provide substantive and useful geospatial cloud services to enterprise grade clients, we will need several data center locations built out, running our specialized server hardware.

### ***The Innovation (recommended length: 1-3 pages)***

Briefly describe the innovation.

- Data handling system that can communicate in a decentralized manner in order to process and store data from other spatial sensors and satellites, allowing analysis of this information to be done on site in extreme environments, reducing the time necessary to gain actionable insight from sensor data.

At what stage of technical development is the innovation? (A more detailed description can be provided in the Technical Discussion and R&D Plan, as described below).

- Our database research project has moved through two iterations of preliminary research, alongside a customer discovery process involving our company's commercial interests in autonomous mapping and advertising analytics.  
  
Adder's general efforts in these areas have informed our future development needs, as our current databasing solutions have proven inadequate for our autonomous mapping development plans.

Describe the key technical challenges and risks in bringing the innovation to market.

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### ***Which of these will be your focus in the proposed Phase I project?***

- Designing a Spatial data engine that can efficiently store and analyze multi-dimensional data on the scale of terabytes per day, ingesting millions of documents from numerous sources. More specifically, the underlying data structures and algorithms that allow for efficient storage will be researched further within Phase 1. Without understanding the

Computer Science of multidimensional data, we will not be able to design an efficient database. These systems need to be designed from the ground up with a specific structure in mind. Doing so will allow us to have 10-50x performance over general databases with functionality for multidimensional data built in.

***Describe the status of the intellectual property associated with this project and how you plan to protect it.***

Intellectual property generated at Adder Mobile Technologies is secured first with our employment agreements and contracts, which specifically detail the rights of Adder to retain any and all intellectual property associated with research and development projects executed in house. Additionally, we require the same control of intellectual property from subcontractors that assist with projects relevant to or in support of Adder.

For this particular project, Adder will seek to protect the processes and systems associated with these innovations via USPTO issued utility patents, claiming any and all innovations that stem from our research.

***NSF Lineage:***

At the time of submission, Adder has received a single, small NSF grant from the University of Louisville, for \$2,500, to begin work on this project. This grant was awarded after completing the majority of planning activities for the innovation.

Our company joined the NSF iCorps with the help of the University of Louisville, Kentucky, to receive assistance in our research and development commercialization plan, and we're working with our state SBIR program director to advise and assist in this proposal process.

This grant, totaling \$2,500, is to be allocated for use in the University of Louisville's LaunchIt program, designed to aid small businesses or entrepreneurs in the technology development process. This program will begin on August 26th, 2019.

The Principal Investigator of the Geode project, Ian Gerard, will also serve as PI for this program. Russell Kimberling will be attending this program to hone their skills in the highly technical enterprise services market.

***The Company/Team (recommended length: 1-3 pages)***

The key participants in this project will be Ian Gerard, Brendan Elliott, Russ Kimberling, Carlos Rincon, Miles Moscara, Bray Torres, Kevin Wiley, Christian Kotscher, Zach Pousman, and Jeremy Fox.

Ian Gerard, the Principal Investigator, will serve as the project manager, ensuring milestones and goals are hit while maintaining a high quality of work standard.

Brendan Elliott

Russ Kimberling

Carlos Rincon

Miles Moscara

Bray Torres

Kevin Wiley

Christian Kotscher

Zach Pousman

Jeremy Fox will serve as a network systems engineer, maintaining distributed cloud systems, and assisting with the implementation of CUDA-enabled data processing units, as well as integrating various aspects of the machine learning space to assist with optimizing data analysis and storage.

*How does the background and experience of the team enhance the credibility of the effort; have they previously taken similar products/services to market?*

The Adder team has all worked on bringing successful geospatial/location data based products to market.

*Describe your vision for the company and the company's expected impact over the next five years. If the company has existing operations, describe how the proposed effort would fit into these activities.*

Our company has been focused on providing a marketable solution to the biggest problem in outdoor advertising: attribution. With this as our focus, we've had to learn how to process billions of location data points per day on limited hardware, which has given us a substantial amount of insight into the problems in the geospatial space.

These challenges led us to an interesting revelation -- that we could utilize our systems and procedures to build systems that not only benefit our own advertising attribution goals, but also,

*Describe the revenue history, if any, for the past three years. Include government funding and private investment in this discussion.*

Adder has sourced \$740,000 in private equity funding since its inception in 2017. Sales began in April 2019 of our initial location analytics services, and we've seen about \$75,000 in total revenue since our founding.

We're planning a \$2 to \$4 million dollar seed round, pending the completion of our version 2.0 platform. This funding will be used to scale our current systems and sales force to a national level, with the intention of increasing sales dramatically over the next two years.

As of 1/1/2020, we have over \$10 million in forecasted revenue from clients we're running validation trials with. This number is expected to grow rapidly after concluding negotiations with Clear Channel Outdoor, Comcast/NBC, and other large outdoor advertising providers, as they are considered our primary data services target due to their massive out of home advertising inventory.

Adder has received one government funding grant -- a Phase 0 NSF grant of \$2,500, which was used to cover expenses associated with the University of Louisville LaunchIT program. This is our local NSF iCorps accreditation program.

*Will you have consultants or subawardees working on this project? If so, what is their expertise, affiliation, and contribution to the project?*

Yes, we do plan to bring in several consultants to assist in Phase I and II on a contractual basis.

India Stewart, an astrophysicist with a degree from the University of Kentucky, will be our orbital mechanics advisor that we intend to hire onto our staff full time, should we win this grant. Her expertise and passion for the field of space exploration will be a huge help to our team, as she compliments our skills and brings her own perspective and expertise to the table.

Alex Gerard, a software engineer and Air Force pilot, will also assist in numerous aspects of this project in an advisory role. His expertise focuses toward software and orbital mechanics. Additionally, he has extensive knowledge in aerodynamics and flight operations.

***Technical Discussion and R&D Plan (minimum length: 5 pages, recommended length: 5-7 pages)***

- Detail CubeSats
- Detail hardware options to go in the CubeSats (and their purposes)
- Detail target application, and the effectiveness of using our clusters
  - Effectiveness of communication b/t nodes as opposed to satellites/earth
  - Speed of analysis and storage
  - Ease of integration through our technology standards
  - Running a query through our specialized system in space vs a non-specialized system on Earth
- Proposed Innovation
  - Satellites
    - Power
    - Storage
    - Processing
    - Communication
  - Spatial Data Structures
  - Spatial Algorithms
  - Custom Database Engine specialized for hardware and environment
  - Analysis Engine

Describe the key objectives to be accomplished during the Phase I research, including the questions that must be answered to determine the technical AND commercial feasibility of the proposed concept.

- Data Structure that allows multidimensional data to be inserted and retrieved efficiently.
- Sharding algorithm that allows are multidimensional data to be uniformly distributed across nodes in the network as well as rebalanced in a continuous, fast-paced manner.
- Database Engine that allows for the following:
  - User-space I/O and Networking
  - Storage Engine for sharding the database per-core per-node
  - Communication/Scheduling between cores and nodes

- Real-time query compiler for execution on multiple nodes
- The reason building a distributed spatial database is hard is because the structures and algorithms they are built on represent hard computer science problems. Traditional structures, like R-trees need to be balanced on inserts as well as traversed on requests/searches. For small data sets, R-trees are very viable, but when working with terabytes to petabytes of data, those data structures do not scale well (reference). These state-of-the-art data structures require fast insertions by appending onto existing structures. When retrieving data, those structures need to be organized in a way that is fast, like hash map (reference). In addition, these data structures also need to be distributable so that when having multiple nodes in a cluster, the data is evenly distributed and stored. That is a lot of requirements for a data structure, which is why researching potential storage solutions is a large part of this process and something that all of Phase 1 should be devoted to. Without having efficient data structures and algorithms in an environment where efficiency is key, there is no need to develop this hardware because it would not be able to store and analyze data fast enough.

Describe the critical technical milestones that must be met to get the product or service to market. Present an R&D plan, with timeline. What are the objectives, and what experiments, computations, etc. are planned to reach those objectives?

- Phase 1: Research for Database
- Phase 2: Hardware?
- Phase 2b: Satellite

#### **4. References Cited.**

Provide a comprehensive listing of relevant references, including patent numbers and other relevant intellectual property citations. A list of References Cited must be uploaded into the system. If there are no references cited in the proposal, please indicate this by putting the statement "No References Cited" into this module.

1. Agarwal, Sarthak, and KS Rajan. 2017. "Analyzing the Performance of NoSQL vs. SQL Databases for Spatial and Aggregate Queries." Scholar Works. University of Massachusetts Press. <https://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1028&context=foss4g>. *Benchmark analysis of database systems from a foundational perspective. SQL vs noSQL systems.*

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[https://en.wikipedia.org/wiki/Spatial\\_database](https://en.wikipedia.org/wiki/Spatial_database)

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Primack, Joel R. (2002). [Debris and Future Space Activities](#) (PDF). Physics Department, University of California. With enough orbiting debris, pieces will begin to hit other pieces, setting off a chain reaction of destruction that will leave a lethal halo around the Earth.

## **5. Biographical Sketches.**

### **Ian Gerard - Principal Investigator**

Education: University of Kentucky. Lexington, KY. Bachelor of Science degree in Natural Resources and Environmental Sciences, focus on Sustainability. 2015.

Relevant Experience: Ian Gerard gained experience in geospatial data plotting, databasing, analysis, and cartography with Leica Geosystems/Hexagon before founding Adder Mobile Technologies. His largest project managed to date is the recently completed Adder 2.0 project which involved daily geospatial workload processing and analysis of over 30 billion data points using GPU and CPU high performance computers purpose built and specialized for web and other applications.

#### Products:

Adder MK I, II, & III Geodatabase - project lead and system architect.

Adder Analytics API/SDK - project lead and system architect.

Adder Marketing Portal - project lead and system architect.

Adder Analytics API/SDK - System architect

Adder Autonomous Cartography System - project lead and system architect.

Provisional patent - outdoor advertising analytics detection methodology

Provisional patent - outdoor ads vector filtering of potential impressions

Provisional patent - dynamic media content delivery based on geopositioning, demographic, and psychographic response data.

Full patent in progress for out of home location conversion methodology, impressions calculation via geopositioning and telemetrics data intersections with established and predicted routes.

### **Brendan Elliott - CTO & Software Development Lead**

#### Education:

Related Work: Brendan Elliott served seven years as a senior developer for ALK technologies (today: Trimble Maps) in geospatial mapping and route optimization, eventually rising to Director of Software Development for their company. Brendan also worked in machine learning and large scale fleet logistics while with ALK.

Brendan Elliott was also the lead developer on the Adder 2.0 GPS analytics backend and overall project, with an emphasis on databasing and hardware operations pertinent to the geospatial data collected. Breakthroughs on the project included near-instant querying of data sets with over 2.5 billion GPS coordinates, containing over 30 billion data points, and analysis/inference of nearby device locations in a non-relational architecture.

#### Products:

ALK - original mobile map APIs and SDKs for iOS platform.

ALK & Nokia - SDK partnership lead

Adder MK III Geodatabase - Software development lead

Adder Analytics Platform 2.0 - Software development lead

Adder Analytics API/SDK - Software development lead

Adder Marketing Portal - Software development lead

Adder Autonomous Cartography System - Software development lead

### **India Stewart - Astrophysicist (BS)**

Education: University of Kentucky, Lexington, KY. Bachelor of Sciences in Astrophysics. 2016.

Related Work: India Stewart worked with the University of Kentucky department of astrophysics and orbital mechanics, completing her undergraduate degree with distinction in 2014. Ms. Stewart has also worked extensively in sustainable agriculture development, managing several farms in the region.

#### Products:

Stellar Cartography Project (NASA SBIR) - secondary advisor for astrodynamics and navigation.

### **Lillie Beiting - Predictive Modeling & Analytics Lead (BA)**

Education: Transylvania University. Lexington, Kentucky. Bachelor of Sciences in Economics

Related Work: Lillie Beiting has specialized in ROI attribution models across multiple software systems, with an emphasis on data integration and database architecture. Her largest project managed to date involved serving as the chief architect in the restructuring of a \$5billion federally-regulated database in preparation for the application of machine learning driven improvements and optimizations to her firm's systems.

#### Products:

Master Database (The Impact Group) - project lead for data models and system integration

Global Ecommerce Portal (Stanley, Black, and Decker) - project lead for database architecture

Adder Mk I - Data structures primary advisor

Adder Mk II - Data structures secondary advisor, monetization and marketing lead advisor

Adder Analytics Platform - Geospatial analytics primary advisor

Adder Marketing Portal - Chief marketing officer

## **Tyler French - Machine Learning & Dev Ops**

Education: University of Kentucky, Lexington, Kentucky. Bachelor of Sciences in Network Administration and Data Systems.

Related Work: Kubernetes and Docker implementations for numerous distributed enterprise networks make Tyler French a critical component of helping our team work on the right AI and deep learning models. He assists in the maintenance of version control and virtualization of our own models, we ensure maximum training efficiency.

### Products:

Adder Mk II - Network scheduling primary advisor, lead developer on Docker containerization prototype of Adder as a service.

Adder Autonomous Cartography System - Machine learning model containerization lead developer.

## **Jeremy Fox - Network Code & Scripting**

Education: Western Kentucky University, Bowling Green, Kentucky. Bachelor of Sciences in Computer Science w/ Certificate in Network Administration. 2013.

Related Work: The Adder 2.0 geocoding, tile server, and unique coordinate system was highly influenced by Mr..Fox.

Jeremy Fox has also worked extensively in hardware troubleshooting and fault testing from his time as a circuitry technician with Harmon/Kardon.

### Products:

Adder Autonomous Cartography System - Research lead, prototype software development lead.

## **6. Budget and Subaward Budgets.**

### **Line A - Senior Personnel**

#### Ian Gerard

*Title:* CEO, System Engineer & Principal Investigator (BLS: 17-2000)

*Time Commitment:* 6 Months

*Salary:* \$4,000/mo

*Responsibilities:*

- Definition, management and scheduling of all project goals, development, milestones, budgets, and team leaders.

#### Brendan Elliott

*Title:* Senior Software Engineer (BLS: 17-2000)

*Time Commitment:* 6 Months

*Salary:* \$9,000/mo

*Responsibilities:*

- Management and scheduling of software development goals, development milestones, budgets, and team members.
- Direct correspondence and cooperation with Lead Database Engineers and Lead Astrophysics Engineer

#### Carlos Rincon

*Title:* Database Engineer (BLS: 15-1243)

*Time Commitment:* 6 Months

*Salary:* \$4,000/mo

*Responsibilities:*

- Development of database structures including insert, index, read, and destroy operations.
- Direct correspondence with the Lead Software Engineer and Lead Astrophysics Engineer.

## India Stewart

*Title:* Astrophysics Specialist (BLS: 19-2010)

*Time Commitment:* 6 Months

*Salary:* \$4,000/mo

*Responsibilities:*

- Advise and facilitate research and design of astrodynamical navigation systems.
- Advise on autonomous cartography methodologies and their relationships to orbital mechanics, as well as intersolar and extrasolar navigation.

## **Line B - Other Personnel.**

Jeremy Fox

Lillie Beiting

Miles Moscara

Bray Torres

Roman Punsky

## **Line C - Fringe Benefits.**

N/A, No fringe benefits will be allocated for team members on this project.

## **Line D - Equipment.**

N/A, Equipment needed for Phase I is already available at our facility.

## **Line E.**

*Line E.1 - Travel.*

- Airfare  $((\$450) \times 2) = \$900$
- Lodging  $(((\$200) \times 3) \times 2) = \$1,200$
- Vehicle Rental  $((\$200) \times 3) = \$600$
- Meals  $((\$100) \times 3) \times 2 = \$600$
- Incidental/Registration Fees  $((\$200) \times 3) = \$600$   
Total = \$3,900

No work travel is planned for this project beyond normal commutes and attending the NSF grantee workshop.

*Line E.2*

N/A, not permitted

**Line F - Participant Support Costs.**

N/A

**Line G.1 - Materials and Supplies.**

**Line G.2 - Publication Costs/Documentation Costs.**

N/A, not permitted

**Line G.3 - Consultant Services.**

Letters of Collaboration.

Consultant Rate.

Biographical Sketch.

**Line G.4 - Computer Services.**

**Line G.5 - Subawards.**

**Line G.6 - Other.**

**Line I - Indirect Costs.**

**Line K – Small Business Fee.** Provide the calculation that was used to arrive at the amount requested.

$$[(\$225,000) \times (.07)) - \$750] = \$15,000$$

## **7. Budget Justification.**

The Budget Justification is uploaded in the Budget Module of FastLane as a single PDF file.

Provide details for each non-zero line item of the budget, including a description and cost estimates.

Identify each line item by its letter and number (e.g., G.5 - Subawards).

Each non-zero line item should be described in the Budget Justification, but several sections also require more specific information as detailed below. Please note that there is no page limit for the Budget and Subaward Budget Justification. You will receive and should disregard a FastLane warning about exceeding the three-page limit when you submit the proposal. In other words, the PAPPG restriction on page limits is not enforced for this solicitation (but all information included in this section must be related to the budget). You can find a sample budget and subaward budget, with justifications, here: <https://seedfund.nsf.gov/fastlane/>

Lines A and B - Personnel. Provide the names and titles of all personnel and a concise description of their responsibilities on the project, including their budgeted time commitment. Provide the actual annual salary information and calculation that justifies the amounts requested.

Line C - Fringe Benefits. Describe what is included in fringe benefits and the calculations that were used to arrive at the amount requested.

Line E.1 -

Domestic Travel. Describe the purpose for domestic travel and acknowledge attendance at the grantee workshop. For trips other than the grantees conference, include the expected number of trips, number of persons travelling, length of each trip, purpose and destination of each trip, and a rough breakdown of the expected cost of each trip.

Line G.1 - Materials and Supplies.

Provide an itemized list of the materials and supplies, with the quantity, unit cost, and total cost for each item. Items with a total line item cost over \$5,000 should have quotes or pricing documentation included as separate pages in the Budget Justification.

Line G.3 -

Consultant Services. Include a copy of the signed Letter of Collaboration. Include a biographical sketch for each consultant.

Line G.5 - Subawards. Include a few sentences describing the scope and objective of the subaward.

Line G.6 - Other. Any single cost of more than \$5,000 should be documented by inclusion of pricing info (e.g. a quote, past purchase order, link to online price list). Line I - Indirect Costs. Provide the calculations that were used to arrive at the amount requested. Please briefly indicate the major cost categories that are included as indirect costs.

Line K – Small Business Fee. Provide the calculation that was used to arrive at the amount requested.

$$[(\$225,000) \times (.07)) - \$750] = \$15,000$$

## **8. Current and Pending Support of Principal Investigator and Senior Personnel.**

### **Information Needed.**

For each listed item, please include the following information: Name of sponsoring organization.

Total award amount (if already awarded) or expected award amount (if pending) for the entire award period covered (including indirect costs).

Title and performance period of the proposal or award.

Annual person-months (calendar months) devoted to the project by the PI or senior personnel.

## **9. Collaborators & Other Affiliations Information**

For the PI and each of the senior personnel, list all institutional affiliations (other employers, consulting relationships, officer/director/trustee roles, etc.) and collaborators (co-authors, scientific partners, student/advisor relationships) that have occurred in the last four years, using the instructions and spreadsheet template found at <https://nsf.gov/bfa/dias/policy/coa.jsp>. This

document will not be viewable by reviewers, but will be used by NSF to help identify potential conflicts or bias in the selection of reviewers. Also see guidance in the PAPPG.

## **10. Facilities, Equipment and Other Resources.**

Our facility is located at 10482 Bluegrass Parkway, Louisville, Ky, 40299. We co-locate our hardware and software development in this facility. With roughly 1400 square feet at our disposal at this location, we have a number of capabilities and available resources that will be relevant to this project.

The Adder HQ facility features 8 physical servers, internal and external 10 Gbit fiber connections, over 250 TB of onsite data storage, and over 500 teraflops of high performance, parallelized computing ability. These machines have room to be scaled up and are at about 50% capacity. We also have plans to add redundancy mechanisms to our cloud systems.

We also have hardware development capabilities tailored toward independent microcontrollers such as the Raspberry Pi, Arduino, Nvidia Jetson, and others. This facility is optimal for software development and AI training on the base data sets.

The secondary location in Richmond, Ky, serves as the base of operations for PCB production, reflow/SMD circuits, non-essential servers. This location can also fulfill 3d printing needs, and hosts backup storage for some of our servers.

Our facilities do not currently feature certified clean rooms, however, we have access to two clean room facilities that would be cost effective for us to lease. We do not anticipate a continuous need for clean room areas after this project, and do not currently intend to adapt our HQ to include a clean room. If a clean room environment is required in a Phase II proposal, we have drawn up plans and budgets for an improvement to our facility at 10482 Bluegrass Parkway, Louisville, KY.

If this facility cannot be brought to the standards that our engineers require for fulfillment of a potential Phase II SBIR proposal, we will seek a solution that can fulfill this need, however, we do not anticipate this outcome.

Our test flight property is located in Henderson, KY, with over 2000 acres of drone and rocket testing space available for miniaturized terrestrial deployments of the proposed innovations in a prototype form.

## **11. Supplementary Documents.**

### **S1. Data Management Plan (required).**

## **S2. Mentoring Plan**

N/A, No post-doctoral scholars will be engaged in the Phase I plan of this project.

## **S3. Letter(s) of Support (strongly recommended; no more than three letters).**

NASA Ames Research Center  
San Jose, California

### Ed Blayney

City Information Officer, Louisville Metro Government  
Louisville, Kentucky

### Christian Kotscher

CEO, MetroTech  
Atlanta, Georgia

## **S4. Company Commercialization History (if applicable).**

The NSF commercialization template is , but Adder has successfully commercialized several platforms that are pertinent to this project.