List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

The following information regarding collaborators and other affiliations (COA) must be separately provided for each individual identified as senior project personnel. The COA information must be provided through use of this COA template.

Please complete this template (e.g., Excel, Google Sheets, LibreOffice), save as .xlsx or .xls, and upload directly as a Fastlane Collaborators and Other Affiliations single copy doc. Do not upload .pdf.

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There are five separate categories of information which correspond to the five tables in the COA template:

COA template Table 1:
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COA template Table 2:
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COA template Table 3:
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- **The individual's Ph.D. advisors; and**
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List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department (optional)
Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and
To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
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For "Last Active Date" and "Last Active" columns dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.
"Last Active Date" and "Last Active" columns may be left blank for ongoing or current affiliations.

<u>Table 1:</u> List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Dabby, Diana S	Franklin W. Olin College of Engineering	current
		MIT, Venture Mentoring Service	current
		MIT, Research Affiliate (LIDS)	current

<u>Table 2:</u> List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:	none			

<u>Table 3:</u> List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Stevens, Kenneth N	MIT	EECS (d. 2013)

T:	none		

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	none			
A:	none			
C:	none			

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to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	none			
E:	none			

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	Kingery, Jacob A	Athena Health	current

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	Lieberman, Howard R	none	

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T:			

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COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
NSF 18-515

☐ Special Exception to Deadline Date Policy

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)
IIP - I-Corps

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				133432760	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
061519057

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
Franklin W. Olin College of Engineering

AWARDEE ORGANIZATION CODE (IF KNOWN)
5300017254

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
Franklin W. Olin College of Engineering
1000 Olin Way
Needham, MA. 024921200

NAME OF PRIMARY PLACE OF PERF
Franklin W. Olin College of Engineering

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
Franklin W. Olin College of Engineering
1000 Olin Way
Needham ,MA ,024921200 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) ☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS

☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **I-Corps Teams: Chaotic System Variability: Applications to Music for Audio and MIDI Formats**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **50,000**	**6** months	**05/01/19**	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☒ TYPE OF PROPOSAL **Research**

☐ HUMAN SUBJECTS Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED
_____
☒ COLLABORATIVE STATUS
Not a collaborative proposal

PI/PD DEPARTMENT

PI/PD POSTAL ADDRESS
Needham, MA 024921245
United States

PI/PD FAX NUMBER
781-292-2505

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **Diana Dabby**	**PhD**	**1995**	**781-292-2551**	**diana.dabby@olin.edu**
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide (PAPPG). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

Certification Regarding Conflict of Interest

The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of PAPPG Chapter IX.A.; that, to the best of his/her knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in FastLane.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Proposal & Award Policies & Procedures Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Proposal & Award Policies & Procedures Guide.

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:
(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Proposal & Award Policies & Procedures Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR) (This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Chapter IX.B. , the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research. The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

Certification Regarding Federal Tax Obligations

When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations. By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:
(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

Certification Regarding Unpaid Federal Tax Liability

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

Certification Regarding Criminal Convictions

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Criminal Convictions:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has not been convicted of a felony criminal violation under any Federal law within the 24 months preceding the date on which the certification is signed.

Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME		

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER

Project Summary

I-Corps Teams: Chaotic System Variability: Applications to Music for Audio and MIDI Formats

Overview:

Key words: chaotic systems, dissipative chaotic systems, Lorenz equations, music, musical variation, MIDI, mashup

Our team (CantoVario) plans to undertake customer discovery, the results of which will help us find a product-market fit for a new technology that creates musical variations of existing songs. Variations of songs in continuous-time (audio) and discrete-time (MIDI) formats are possible. Music is the most emotional art form yet arguably demands the greatest skill to actualize; making music requires time, effort, training, and money. Those who love music have to settle for the passive act of listening rather than the more active art of creating. CantoVario enables anyone—amateur, student, or professional—to fuse their own creativity with the songs that fill emotional needs in their own lives, e.g., reflection of mood, release from stress, and so on.

Intellectual Merit:

The Lorenz equations, a system of three first order nonlinear differential equations that exhibit chaotic dynamic behavior, arise in applications ranging from cardiology to turbulence. Most engineers seek ways to eliminate chaos; yet in its 'chaotic regime', the Lorenz system possesses a natural mechanism for variability due to the sensitivity of its solutions to initial conditions. This built-in variability can be harnessed to produce variations of a context-dependent sequence of symbols, such as a musical work; specifically, a chaotic mapping technique enables the transformation of an ordered input into a variant ordered output. Furthermore, the variant output differs from but maintains a recognizable similarity to the input. The method includes parsing the input into an ordered sequence of original elements $\{N_i\}$, the original elements sequentially indexed by successive integer values $i=1,\ldots, i_{max}$. For each i, a selection algorithm determines whether N_i is a candidate for modification or replacement, thus becoming a "receptor element." A substitution or modifying algorithm then operates on at least one of the receptor elements by varying or replacing it with a substitution element. The resulting ordered set of original and substituted or modified elements constitutes the variant output.

Broader Impacts:

As a potentially disruptive technology, CantoVario can alter how people interact with music on and offline. It takes "personalized music" beyond playlists and song recommendations, allowing music lovers to directly participate in the creative process. For musicians, it enables new avenues for developing and presenting original music to listeners for a more interactive user experience. Finally, no differentiator yet exists that distinguishes one digital music service from another; they all advertise the same basic products—recommendations and playlists. By offering direct interaction with songs and playlists to create new songs that can be shared with others, CantoVario offers a unique experience for music streaming service customers.

Music is a highly context-dependent application where each note or musical event is determined by the preceding notes and events, and each note or event foreshadows those to yet come. That this technique produces musical variations that can be analyzed as well as used for musical means suggest that the technique can be applied to other sequences of context-dependent symbols, in science as well as the arts. Furthermore, it can stimulate interest in engineering for students K-12 and beyond by linking science with something they love—music.

TABLE OF CONTENTS

For font size and page formatting specifications, see PAPPG section II.B.2.

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

I-Corps Team

Proposal Principal Investigator (PI) and Entrepreneural Lead (EL): Diana Dabby (diana.dabby@olin.edu)

Diana Dabby has taught at MIT, Tufts and Juilliard, and holds degrees in electrical engineering from C.C.N.Y. and MIT. She is Music Program Director and Electrical Engineering faculty at Olin College where she teaches orchestration, composition, performance, and signal processing. As a concert pianist and composer, her work has been heard at Boston's Jordan Hall, Symphony Hall, Tanglewood, in New York at Carnegie-Weill Recital Hall and Merkin Concert Hall, as well as on both coasts and abroad. Her work with musical variation has been featured on NPR member station WBUR (2004) and NPR's Weekend Edition (2007), in *Science* (2008) and the *Boston Globe* (2013), as well as at a number of invited concert/lectures. A new web application, Canto*Vario*, is currently under development with the MIT Venture Mentoring Service (VMS) program. Awarded three patents, this work was selected for MIT's VMS Demo Day 2014, Entrepreneurial Edge Showcase 2017, and the MIT Innovation Corps (2018), a program sponsored by the National Science Foundation. As an orchestrator, Dabby has created 127 arrangements of symphonic works for the Olin Conductorless Orchestra, ranging from 6 to 26 players (2002 – present). Recent compositions include *Who was Wissam Eid?* (2017)*, Fuente y Variación* (2013)*, Tre Studi di Colore* (2012)*,* and *September Quartet* (2011) which received its world première on the tenth anniversary of 9/11. The world première of *Parallel Voices—Distant Mirrors* (2018) for bass/alto flutes, voice, piano, and soundtrack featured a new listening experience for the audience: seat location determined the variation path heard through the soundtrack. All of the above can be heard on YouTube.

Technical Lead (TL): Jacob Kingery (jacob.a.kingery@gmail.com)

Software developer Jacob Kingery graduated from Olin College in 2016 where he majored in electrical engineering and played trumpet in jazz, wind, and orchestral ensembles, often in principal roles. He has been the software developer for CantoVario since October 2014 and built the current CantoVario web and mobile apps.

Industry Mentor (IM): Howard Lieberman (howardlieberman@me.com)

Howard Richard Lieberman has three decades of experience as an innovator in audio, computing, and education. He founded the Silicon Valley Innovation Institute to develop and apply a conscious innovation model internationally, in order to turn Vision into Value. He also founded five companies—Interactive Visual Analysis Languages (INTERVAL), Integrated Acoustics, Escatech Media Inc., Dorado, and Asonda Corp.—and has invented and brought to

market new technologies at Bose Corporation, Apple Computer, as well as the companies he founded, including hardware and adaptive content software architectures. He has developed digital signal processing acoustical measurement systems at Bose, JBL, Boston Acoustics, and Apple Computer, contributed to standards committees, and consulted to Tektronix, 3Com, Amdal, Cienna, Sun, Kurzweil, Ensoniq, JBL, Walmart, Harman Intl., Bose, Apple, Boston Acoustics, and Fishman Transducers. Prior to founding the Silicon Valley Innovation Institute, Mr. Lieberman was the Dean of External Affairs and Distinguished Lecturer of Innovation Management and Aesthetic Engineering for Cogswell Polytechnical College, a 120-year old technical institution in Silicon Valley. He has also worked in Intellectual Property and been a member of the Silicon Valley Intellectual Property Law Association (SVIPLA), the Intellectual Property Society (IPS), the Licensing Executives Society (LES), and has recently chaired a Summit on the Globalization of Technology, as well as the SCI3 Foundation Board. Howard Lieberman holds a BS in Physics from the City University of New York, an MS in Electrical Engineering from the University of Rhode Island and has done Post Graduate work at the Massachusetts Institute of Technology in Acoustics & Image Processing.

Lineage of the Proposed Innovation:

NSF MIT I-Corps program. (Site Program award #347267 and #1735671, Program Officer Anita LaSalle) conducting 20+ customer discovery interviews

I-Corps Teams: Chaotic System Variability: Applications to Music for Audio and MIDI Formats

A chaotic mapping technique, disclosed in [1], [2], produces variations of a sequence of context-dependent events. The mapping is expressed by a selection function

$$f(x_{2,j}) = \begin{Bmatrix} e_{i=g(j)}, & j = g(j) \\ E_j, & j \neq g(j) \end{Bmatrix} = E'_j,$$

where E'_j represents any event of the variation, $e_{i=g(j)}$ denotes any pitch, chord, phrase, beat, note rhythmic value, note-group, and/or any other musical event from the source work that will appear unchanged in the variation as a result of the condition $j = g(j)$, and E_j represents any musical event in the variation produced by the chaotic mapping technique in conjunction with a designated variation procedure whenever $j \neq g(j)$. The term $g(j)$ is assigned the value of the index i of the least $x_{1,i}$ for which $x_{2,j} \leq x_{1,i}$.

A first chaotic trajectory $\{x_{1,i}, y_{1,i}, z_{1,i}\}$, indexed on i, with initial conditions $(x_{1,1}, y_{1,1}, z_{1,1})$ is launched. A second chaotic trajectory $\{x_{2,j}, y_{2,j}, z_{2,j}\}$, indexed on j, with initial conditions $(x_{2,1}, y_{2,1}, z_{2,1})$ is simulated. A selection function $w(x_{2,j}) = g(j)$ takes each x-value of the second chaotic trajectory (and/or y- z-values of same) and determines $g(j)$, where $g(j)$ is assigned the value of the index i of the least $x_{1,i}$ such that $x_{2,j} \leq x_{1,i}$. If the selection function results in $j = g(j)$, then events $e_{i=g(j)}$ will occur in the same spot in the variation as in the source piece. But if $j \neq g(j)$, then a new event E_j is substituted, possibly altered further with a designated variation procedure such as reflection about a given pitch.

One inherent advantage of the chaotic mapping technique over a probabilistic scheme results from its built-in 'controls' or 'sliders' that determine the amount of variability—all arising from a natural mechanism for variability present in chaotic systems, i.e., the sensitive dependence of chaotic trajectories to initial conditions. Thus, the degree to which the initial conditions chosen for the second chaotic trajectory differ from those assigned to the first trajectory will directly affect the degree of variability present in any given variation.

Customer Discovery conducted as part of the MIT SPARK Program provided a practical context for how the above described musical variation technology can fit in today's commercial environment. Specifically, 32 SPARK Program interviews with students (ages 12-22) revealed that 88% or more listen to music daily, access streaming services, share music, and experiment with music. Furthermore, they highly value music as part of daily life, and if given the chance to add a personal touch to their music, they would. So far, these results support a product-market fit for the Canto*Vario* team project. Our SPARK Program experience moved us farther toward twin goals: commercialization and societal impact through customer discovery and business model exploration.

Description of the Potential Commercial Impact

Canto*Vario* acts as a musical change agent that takes "personalized music" beyond playlists and song recommendations. For the first time, music lovers, i.e., just about

everyone, can bring their own creativity to the music they care about, i.e., the songs providing the soundtrack for their lives. The Canto*Vario* project opens the door to a new paradigm for music where songs evolve and undergo transformation alone or in tandem with other songs, at the click of a button.

The choice of music as an application for the chaotic mapping technique is deliberate. Music is a highly context-dependent application where each note or musical event is determined by the preceding notes and events, and each note or event foreshadows those yet to come. That this technique produces musical variations that can be analyzed as well as used for musical means suggest that the technique could be applied to other sequences of context-dependent symbols, such as those that define image, text, film, and video. Furthermore, it can serve as an idea generator for media practitioners in general, as well as stimulate interest in engineering for students K-12 and beyond by linking science with something they love—music.

Project Plan

As a result of our SPARK Program customer discovery, we 1) expanded our customer base to consumers ages 12+ while narrowing it to those who **listen** to music daily, **share** music, and **experiment** with music (**LSE** customers), and 2) inserted "add a personal touch" to our value proposition ("Reduce the time necessary to create new songs from the songs you love by hours or days—and add a personal touch.") Our findings support three related needs/desires: 1) LSE customers want to directly interact with their music (add a personal touch). 2) Music holds great value in their lives; they 'need' music. 3) No paradigm-shifting differentiator exists to distinguish digital music services, yet all our interviewees listen to music via streaming services, suggesting a market opportunity. Our current best guess is that Canto*Vario* will provide software to a variety of markets, devising its models of selling (licenses, subscriptions, downloads, etc.) and products according to its customers. Specifically, further customer discovery will help refine our value proposition and determine the best customer segment, whether it be consumers, professionals, or large music companies. As we learned early on: Better test than sorry.

References cited:

[1] Dabby, D. S. Improved Method of and Apparatus for Computer-Aided Generation of Variations of Music and other Sequences of Symbols, Including Variation by Chaotic Mapping. Utility patent application 13/192,380, filed USPTO, July 2011. Granted March 2016.

[2] Dabby, D. S. Method and Apparatus for Computer-aided Variation of Music and other Sequences, including Variation by Chaotic Mapping. Continuation in Part 14/264,612, filed USPTO, April 2014. Granted March 2016.

Biographical Sketch

Diana S. Dabby
Franklin W. Olin College of Engineering
1735 Great Plain Avenue, Needham, MA 02492-1245

A. Professional Preparation

MIT Electrical Engineering and Computer Science, Post-Doctoral Fellowship 1995–97, Cambridge, MA
MIT Electrical Engineering and Computer Science PhD 1995, Cambridge, MA
MIT Electrical Engineering and Computer Science S.M. 1991, Cambridge, MA
City College of New York Electrical Engineering BEng. 1987, New York, NY

B. Appointments

2010 – present: Music Program Director, Franklin W. Olin College of Engineering
2005 – present: Founding Faculty and Associate Professor of Electrical Engineering and Music, Franklin W. Olin College of Engineering
2000 – present: Research Affiliate, Laboratory for Information and Decision Systems, MIT
2000 – 2005: Founding Faculty and Assistant Professor of Electrical Engineering and Music, Franklin W. Olin College of Engineering.
Jan – May 2002: Adjunct Graduate Faculty, The Juilliard School
Jan – Dec 2000: Tufts University Fellow, funded by Electrical Engineering and Computer Science
1998 – 1999: Visiting Lecturer in Electrical Engineering and Computer Science, Tufts University
1999: Visiting Lecturer in Music, Tufts University
1998: Visiting Lecturer in Electrical Engineering and Computer Science, MIT
1997 – 1998: Visiting Assistant Professor of Music, Middlebury College
1997: MIT Artist in Residence
1997: Tufts University Summer Teaching Fellow
1995 – 1997: Postdoctoral Associate in Electrical Engineering and Computer Science, MIT

C. Products

(Ci) Products most closely related to the proposed project:

1. Dabby, D. S. Method and Apparatus for Computer-Aided Mash-up Variations of Music and other Sequences, Including Mash-up Variation by Chaotic Mapping. Utility patent application 16/144521, filed USPTO Sept. 2018.

2. Dabby, D. S. Method and Apparatus for Computer-aided Variation of Music and other Sequences, including Variation by Chaotic Mapping. Continuation in Part 14/264,612, filed USPTO, April 2014. Granted March 2016.

3. Dabby, D. S. Improved Method of and Apparatus for Computer-Aided Generation of Variations of Music and other Sequences of Symbols, Including Variation by Chaotic Mapping. Utility patent application 13/192,380, filed USPTO, July 2011. Granted March 2016.

4. Dabby, D. S. Trademark applications 87/272,552 EnginArt™ and 86/274,215 CantoVario™, submitted May 2014. Computer software for processing digital music files; computer software for creating and editing music and sounds; music-composition software. Registered March 2015 and Dec. 2014, respectively, by the United States Patent and Trademark Office (USPTO).

5. Dabby, D. S. "Creating Musical Variation," *Science*, April 4, 2008, 320, (5872), pp. 62-3. Invited Perspectives article.

(Cii) Products not related to the proposed project:

1. Dabby, D. S. *Parallel Lives—Distant Mirrors* for piano, bass and alto flutes, voice, and soundtrack. World Première, Wellesley College Concert Series. Performed by Yong Su Clark (flutes), P. Lucy

McVeigh (mezzo-soprano), and Jongsun Lee (piano). Comprising 5 movements, the work explores parallel universes in Iraq and the United States. It offers the audience a concert of "Variations and Shadows" where seat location determines what the audience hears. The world première performance utilized sound-focusing technology developed by Kevin Brown of Brown Innovations. https://youtu.be/xSqE22X4I8U

2. *Who was Wissam Eid?* for violin, cello, and piano. World première. One of 6 faculty and student commissions from a Presidential Innovation Grant (Wellesley, Babson, Olin) performed by Gabriela Diaz (violin), David Russell (cello), and Lois Shapiro (piano), April 2017. https://youtu.be/Ra_AoA8SUsY

3. *Fuente y Variación* (source and variation) for piano. World première. Commissioned by pianist Jongsun Lee for her invited artist concert sponsored by Youngsan Art Hall, Seoul, Korea, May 2013. https://www.youtube.com/watch?v=3vVeYwW1VNY

4. *Tre Studi di Colore*, three études for solo piano. Recorded by pianist Jongsun Lee at Mozart Hall, Seoul, Korea, Dec. 9, 2013. https://www.youtube.com/watch?v=mRrJhR4OmEQ

5. *September Quartet*, a five-movement work for chorus, winds, brass, percussion, violin and piano, commissioned by Tufts University for the New Music Ensemble, John McDonald, Director, in commemoration of the Tufts Sesquicentennial. World Première on the Tenth Anniversary of 9/11 at Distler Performance Hall, Granoff Music Center, Tufts University. https://www.youtube.com/watch?v=UQj2EmfFgAg (In the process of establishing this new link, the previous 500 views and comments were lost.)

D. Synergistic Activities

1. Developed, taught, and created curricular materials for 7 courses of Signals and Systems, and 6 courses of Digital Signal Processing, for the ECE Program at Olin College of Engineering, 2003 – 2019.

2. Developed, taught, and created curricular materials for a module comprising two 1.5 hour classes on the mathematics underpinning music for "Engineering the Acoustical World," a new course at Harvard University, John A. Paulson School of Engineering and Applied Sciences, given by Prof. Robert Wood. This module connected the wave equation, overtone series, tuning, string harmonics, and modal scales. Feb. 2018.

3. Dabby, D.S. (2017). The Engineers' Orchestra—a conductorless orchestra for our time. In D. Baraiktarova & M. Eodice (Eds.), *Creative ways of knowing in engineering* (pp. 23-58). Cham, Switzerland: Springer Nature. https://link.springer.com/chapter/10.1007/978-3-319-49352-7_2

4. Founder and developer of the *Olin Conductorless Orchestra* (2002-present), an ensemble—minus conductor—featuring instrumentalists in leadership, communicative, and collaborative roles. The Olin Conductorless Orchestra is the only conductorless orchestra composed of engineers—in the world. Responsibilities include re-orchestrating symphonic works (chosen by the students) for the orchestra's eclectic combination of instruments; providing constructive commentary on a weekly basis; coaching/rehearsing/guiding from the side or up front, as needed; bringing in Boston area musicians to provide external feedback to the orchestra 3-4 times each semester.

5. Dabby, D. S. 127 arrangements (re-orchestrations) of works by Bach, Handel, Haydn, Mozart, Beethoven, Schubert, Schumann, Berlioz, Dvorak, Suk, Tchaikovsky, Smetana, Wagner, Saint-Saens, Mussorgsky, Rimsky-Korsakov, Puccini, Holst, Bartok, Prokofiev, Stravinsky, Gershwin, Copland, Shostakovich, Piazzolla, Bernstein, Lee Jisu, John Williams, John Powell, Arturo Marquez, Murray Gold, Elmer Bernstein, and Ramin Djawadi, for various combinations of instruments comprising the Olin Conductorless Orchestra, ranging from 6 to 26 players (2002 – present). https://www.youtube.com/watch?v=BA5F48usRIo

Biographical Sketch

Jacob A. Kingery

A. Professional Preparation

Olin College of Engineering B.S. 2016
Needham, MA

B. Appointments

2016 – present: Lead Member of Technical Staff, athenahealth, Inc.

C. Products
(Ci) Products most closely related to the proposed project: None.

(Cii) Products not related to the proposed project: None.

D. Synergistic Activities

1. Principal trumpet, the Olin Conductorless Orchestra, 2012 – 2016

2. Served as a Co-Navigator of the Olin Conductorless Orchestra, 2013 – 2015; worked to facilitate effective rehearsals while maintaining a collaborative atmosphere.

Biographical Sketch

Howard R. Lieberman

A. Professional Preparation

CUNY Brooklyn College	Brooklyn, N.Y. B.S. Physics 1975
University of Rhode Island	Kingston R.I. M.S.E.E. 1980
MIT	Cambridge, M.A. Course work in acoustics and image processing 1983

B. Appointments

2005-2018	Chairman, Silicon Valley Innovation Institute 2005 – present
2013-2017	Science Engineering Technology Advisor, DARPA
2000-2005	Dean of External Affairs, Cogswell Polytechnical College
1994-2000	CEO ESCAtech Media Inc.
1990-1994	World Wide Product Manager Sound, Music, DSP and MIDI, Apple Computer
1990-1994	Electro-acoustical Systems Manager, Apple Computer (dual appointment)
1980-1989	New Ventures Manager, Bose Corporation

C. Products

1985 Bose-Ensoniq Acoustic Wave Piano, first self-contained digital piano. Bose Corporation
1990 Acoustic Guitar Amplification Systems, first acoustic guitar amplifier. Integrated Acoustics.
1992 Apple Powered Loudspeakers, first dedicated computer sound systems.
1992 Apple Audio Video Monitors, first computer monitors with built in speakers.
1993 Apple PlainTalk Microphone, first speech recognition microphone; shipped 20,000,000 units.

D. Synergistic Activities

1976-1979	Taught electro-acoustics, metrology, statics, dynamics and linear systems. University of Rhode Island and Rhode Island Junior College
2002-2004	Created and taught Aesthetic Engineering for electrical engineering majors Cogswell Polytechnical College
2003-2005	Created and taught Innovation Management Program; Evolved into Innovation and Entrepreneurship MBA Degree Program
2005-2018	Founded and ran Silicon Valley Innovation Institute to connect innovators and decision makers; presented over 100 programs to over 1000 individuals
2019	Founded International Composers Collaborative group of performing-presenting composers who recently met at Juilliard.

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Franklin W. Olin College of Engineering

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Diana Dabby

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**0**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**0**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**45,000**	
TOTAL OTHER DIRECT COSTS				**45,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**45,000**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Indirect costs (Rate: 100.0000, Base: 5000)**					
TOTAL INDIRECT COSTS (F&A)				**5,000**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**50,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**50,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Diana Dabby

ORG. REP. NAME*

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Franklin W. Olin College of Engineering

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Diana Dabby

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**0**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**0**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**0**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**45,000**	
TOTAL OTHER DIRECT COSTS				**45,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**45,000**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**5,000**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**50,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**50,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Diana Dabby

ORG. REP. NAME*

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget Justification

G6. Other
As required by the solicitation, **$45,000** has been allocated as Other Direct Costs.

$6,400 is requested for the three members of the team in this proposal to attend the I-Corps program in one of the spring 2019 cohorts.

Purpose of Trip/ Location	No. of Travelers	Lodging	Per Diem	No. of Days	Transportation.	Total
Kick Off, Nashville, TN	3	$150	$75	3.5	$650	$4,088
Lessons Learned, Nashville, TN	3	$150	$75	2.5	$283	$2,312

$4,500 is requested for a registration fee of $1,500 per person for the three members of the team as required by the solicitation.

$34,100 will be used for customer discovery activities by the team, particularly travel to relevant companies, nonacademic conferences and trade shows. The team will require explicit written approval from a NSF I-Corps program director prior to undertaking any travel to an academic conference or any international travel under the I-Corps award.

H. Indirect Costs
Per the solicitation, **$5,000** has been included for Indirect Costs.

Current and Pending Support

(See PAPPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Diana Dabby

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: I-Corps Teams: Chaotic System Variability: Applications to Music for Audio and MIDI Formats

Source of Support: National Science Foundation

Total Award Amount: $ 50,000 Total Award Period Covered: 05/01/19 - 10/31/19

Location of Project: Franklin W. Olin College of Engineering

Person-Months Per Year Committed to the Project. Cal:3.00 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

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Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See PAPPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Jacob Kingery

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: I-Corps Teams: Chaotic System Variability: Applications to Music for Audio and MIDI Formats

Source of Support: National Science Foundation

Total Award Amount: $ 50,000 Total Award Period Covered: 05/01/19 - 10/31/19

Location of Project: Franklin W. Olin College of Engineering

Person-Months Per Year Committed to the Project. Cal: 0.50 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

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Current and Pending Support

(See PAPPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Howard Lieberman

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: I-Corps Teams: Chaotic System Variability: Applications to Music for Audio and MIDI Formats

Source of Support: National Science Foundation

Total Award Amount: $ 50,000 Total Award Period Covered: 05/01/19 - 10/31/19

Location of Project: Franklin W. Olin College of Engineering

Person-Months Per Year Committed to the Project. Cal:0.50 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

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Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

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 USE ADDITIONAL SHEETS AS NECESSARY

Facilities, Equipment and Other Resources

While participating in I-Corps, no facilities, equipment, resources, or major equipment will be purchased. Resources that already available to the team are not expected to result in extra charges or use of funds.

FACILTIES:

The team will use Olin College of Engineering office space at Olin Way, Needham, MA 02492

EQUIPMENT:

None

OTHER RESOURCES:

None

Diana Dabby (PI and Entrepreneurial Lead) will be leading the team and the customer discovery process.

Jacob Kingery (Technical Lead) will be taking an active part in the customer discovery process.

Howard Lieberman (Industry Mentor) will be responsible for advising the team to help ensure progress in the customer discovery process.

Data Management Plan

Only public data from this project will be what will be shared by the team as part of its participation at the workshops, and reporting required for I-Corps.