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PI/PD Name: David S Hachen

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☐

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☒

Ethnicity Definition:
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Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
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White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

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PI/PD Name: Omar Lizardo

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☒ Hispanic or Latino ☐ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

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PI/PD Name: David Nickerson

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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PI/PD Name: Zoltan Toroczkai

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
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- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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PI/PD Name: Lijuan Wang

Gender: ☐ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

Disability Status:
(Select one or more)
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- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☐ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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

SUGGESTED REVIEWERS:

Sinan Aral
Stanley Wasserman
Steve Borgatti
Sy-Miin Chow

REVIEWERS NOT TO INCLUDE:

Not Listed

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 13-1

NSF 12-614 **12/03/13**

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

SMA - Interdiscp Behav&SocSci IBSS

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1416813

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
12/03/2013	1	04010000 SMA	8213	824910376	12/05/2013 10:08am S

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

350868188

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

University of Notre Dame

AWARDEE ORGANIZATION CODE (IF KNOWN)

0018408000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

940 Grace Hall
NOTRE DAME, IN 46556-5612

NAME OF PRIMARY PLACE OF PERF

University of Notre Dame

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE

University of Notre Dame
940 Grace Hall
Notre Dame ,IN ,465565612 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)
☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS

☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **Modeling Social Networks as Coupled Dynamic Systems**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **996,213**	**36** months	**09/01/14**	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date _____
PHS Animal Welfare Assurance Number _____

☒ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number **00002462**
Exemption Subsection _____ or IRB App. Date **09/25/13**
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)

PI/PD DEPARTMENT
Sociology

PI/PD FAX NUMBER
574-631-4268

PI/PD POSTAL ADDRESS
747 Flanner Hall

Notre Dame, IN 465564637
United States

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **David S Hachen**	**PhD**	**1983**	**574-631-5745**	**hachen.1@nd.edu**
CO-PI/PD **Omar Lizardo**	**PhD**	**2006**	**574-631-5745**	**olizardo@nd.edu**
CO-PI/PD **David Nickerson**	**PhD**	**2005**	**574-631-7016**	**david.w.nickerson@gmail.com**
CO-PI/PD **Zoltan Toroczkai**	**PhD**	**1997**	**574-631-2618**	**toro@nd.edu**
CO-PI/PD **Lijuan Wang**	**PhD**	**2008**	**574-631-7243**	**wang.172@nd.edu**

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,Part I: the Grant Proposal Guide (GPG). 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).

Conflict of Interest Certification

When the proposing organization employs more than fifty persons, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Conflict of Interest:
By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the organization has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Section IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the organization's expenditure of any funds under the award, in accordance with the organization's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

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 Grant Proposal 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 Grant Proposal 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 Grant Proposal 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, Part II, Award & Administration Guide (AAG) Chapter IV.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.

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

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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:

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* EAGER - EArly-concept Grants for Exploratory Research
** RAPID - Grants for Rapid Response Research

Social networks are dynamic systems in two senses: they evolve as individuals form and dissolve social ties *and* they can be an important diffusion mechanism through which people are exposed to, and possibly adopt, the behaviors, tastes, and attitudes of other individuals. Understanding networks and behaviors as coupled dynamic systems is critical to the advancement of computational social science. A growing literature focused on "social contagion" processes shows that some behaviors and traits (obesity, smoking, happiness, political attitudes) diffuse via network ties, social influence and dyadic role modeling. However, dyadic differences do not have to lead to individuals becoming more similar via a contagion process. Instead, differences can inhibit tie formation in the first place or negatively affect a tie's relative viability once formed. *Ascertaining what types of personal traits are more likely to diffuse through networks and which ones are less likely to diffuse – and thus more likely to drive dynamic network change – is critical to advancing our understanding of the role social networks can play in facilitating social and cultural change.* Unpacking the coupling of networks and behaviors requires longitudinal data on *both* changes in a wide range of behaviors, tastes and attitudes *and* changes in the social ties people have to one another. The project will use unique data that was collected through the PI's NetSense project in which 190 college freshmen were given free smartphones through which data was obtained on who they communicated with over a two-year period. Supplemented with periodic surveys on their behaviors, tastes and attitudes, the data will be used to (1) map out the evolution of student's social networks and changes in their behaviors and (2) model the interconnection between network and behavioral change in order to identify which traits are more likely to diffuse and which traits are more likely to lead to tie dissolution. Since models for coupled dynamic systems involving networks are underdeveloped, this project will rigorously explore the assumptions and utility of a range of different ways to model how networks and behaviors co-evolve.

This project is unique in that it will focus on a wide range of behaviors and traits (ranging from cultural traits to mental health indicators) and explore a wide range of analytic and modeling tools hailing from different disciplines. To that end, the project will have an interdisciplinary team consisting of two sociologists, a political scientist, a psychologist, a physicist and mathematician, and a computer scientist. This interdisciplinary expertise will allow the project to examine many different types of behaviors, assess whether diffusion mechanisms are similar in different arenas, draw upon the models and tools that have been developed in different disciplines, and use the team to disseminate tools, methods and findings widely throughout the behavioral and social sciences.

From an *intellectual merit* standpoint, the proposed work is both part of the fundamental shift in the behavioral and social sciences described in NSF's *Rebuilding the Mosaic* report (Gutmann and Friedlander 2011) *and* an initiative to advance these changes by pushing the frontiers of network science forward by: (1) examining the role that social networks play in diffusing a wide range of behaviors and tastes (health, musical genres, drinking, volunteering, political and social attitudes) of interest to researchers across the various disciplines within the behavioral and social sciences; (2) refining and assessing models for coupled dynamic systems so that researchers have guidelines for what models are appropriate given the behaviors that they are interested in and the network processes that are central to their specific research effort; (3) using longitudinal data to validate these models and ascertain the relative weight of social influence processes, social selection, and tie evolution dynamics in accounting for homophily (similarity among connected persons); and (4) generating new discoveries about both social networks dynamics and behavioral evolution.

In closing, the *broader impacts* revolve around the promotion of interdisciplinary research on dynamic systems across the behavioral and social sciences. The results of this project will help to promote and facilitate the use of advanced tools, models and statistical methods within the social sciences. Further, the team's efforts will encourage and facilitate the collection by others of longitudinal data on both social networks and behaviors using novel and less obtrusive data collection technologies such as smartphones. Moreover, by understanding what traits are more likely to diffuse, this research could lead to interventions that use networks to promote positive behavioral changes. Finally, the planned interdisciplinary effort to disseminate our findings, methods, models and data collection strategies will advance the transformative changes occurring in the social sciences involving new methods, novel and more reliable types of data made possible by new communication technologies, and new ways of thinking about social networks and behavior dynamically.

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*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. Introduction

Individuals create, maintain, and dissolve social relationships by engaging in routine interactions. These interaction events range from deep and engrossing (a one hour phone call; a long dinner conversation) to relatively fleeting and brief (a one-word text message). The relationships constituted via these interactions range in their turn from durable social ties relatively resistant to sudden change ("best friend," "daughter"), to more fleeting connections characterized by low levels of cognitive and emotional salience ("acquaintance," "classmate"). Recent work across the social and computational sciences shows that the web of ties linking persons to one another and the relational events that constitute those ties can be profitably modeled using the tools of social network analysis (SNA) and network science (NS) (Cioffi-Revilla 2010; Lazer et al. 2009; Newman 2010). From this perspective, sets of ties linking persons to one another constitute a social network. Classical network analysis focused on the static modeling of patterns of social ties connecting persons to one another (Wasserman and Faust 1994). More recently, the availability of temporally fine-grained data on social interactions has brought with it a renewed focus on *modeling networks as complex, dynamic systems* (Barrat, Barthelemy, and Vespignani 2008; Boccaletti et al. 2006; Eagle and Pentland 2006). People's networks change as they form and dissolve social ties (a relational state) with others and change the level of interactions (e.g., number of communication events) that they have with them. For instance, two persons may be linked by a durable social tie or share a common contact (a relational state configuration) while engaging in a number of interactions within a given time window (an aggregation of events). State and event dynamics occur at different time scales, ranging from single interactions taking up a few seconds, to longer-term processes of tie formation, tie maintenance and tie decay taking months or even years to play out (Borgatti and Halgin 2011; Burt 2000; Burt 2002; Raeder et al. 2011) .

While it is possible to restrict ourselves to purely topological criteria in characterizing the structure of social networks, research shows that *cultural and behavioral processes matter for understanding the evolutionary trajectory of social networks* (Carley 1999; Lewis et al. 2008; Lewis, Gonzalez, and Kaufman 2012; Pachucki and Breiger 2010). Recent work on the phenomenon of "homophily," namely, the likelihood that two randomly connected persons will match on a given personal trait, demonstrates the importance of culture for network dynamics (Wimmer and Lewis 2010). Changes in network relational states (the maintenance and dissolution of ties) are related to how similar two individuals are in their behaviors and cultural aptitudes, tastes, and values. The relational states and the relational events that define the dynamic evolution of the social network (who is connected to whom) and the personal traits that define the distribution of node characteristics (which persons exhibit which attitudes and tastes or engage in which behaviors) are *coupled dynamic systems* (Carley 1991; Mark 2003). **Modeling social networks thus requires that we specify generative mechanisms that account for both the evolution of relational states (and events) *and* the processes via which persons change (or keep) their traits** (Aral, Muchnik, and Sundararajan 2009; Friemel 2012; Lewis, Gonzalez, and Kaufman 2012; Shalizi and Thomas 2011) .

Because the mechanisms that generate matching across individuals (homophily) are correlated with the probability of observing a tie between them (selection effects), modeling coupled dynamic systems have proved challenging for scientists. The easiest (but also problematic) solution is to assume that one system, usually the network, is stable, such that ties are the "pipes" via which cultural information flows (Borgatti 2005). For example, network effects and social contagion models assume that the social network is stable, or changes at a slower rate than personal traits. This allows researchers to model individual level outcomes (which individuals acquire what trait) as a function of topological features of the social network (who is connected to whom).

The assumption of stable networks was called into question in the 1990s by longitudinal network studies which showed that networks exhibit high rates of temporal instability, even at relatively short time scales such as weeks or month (see special issues of *Social Networks* in 1997 and 2005). Because persons are constantly forming and dropping ties, the composition of personal networks can change over time (Bidart and Degenne 2005; Bidart and Lavenu 2005; Suitor and Keeton 1997). These longitudinal studies shifted attention to social network evolution by modeling tie formation, tie persistence, and changes in ego network size (range), clustering and composition (Burt 2000; Suitor, Wellman, and Morgan 1997; Suitor and Keeton 1997) .

The existence of changing networks makes the stability assumption underlying the network effect and contagion paradigms untenable or only applicable to a small subset of a person's total number of ties (e.g. best friends or close kin). For instance, that such things as happiness, obesity, and cigarette smoking travel mainly via strong, stable ties (close friends and kin), is the simplifying assumption that is made in the recent social contagion studies conducted by Christakis, Fowler and collaborators (Christakis and Fowler 2007; Christakis and Fowler 2008; Fowler and Christakis 2008; Fowler and Christakis 2008). It is clear however, that assuming that networks are stable in order to model change in behaviors via social influence or dyadic role modeling is bound to miss a big chunk of the overall dynamics of any social system. Personal networks are stratified into core and peripheral shells, with close friends and kin forming only a relatively small proportion of the total number of contacts surrounding the individual at any one time (Miritello et al. 2013; Miritello et al. 2013; Roberts et al. 2009; Suitor, Wellman, and Morgan 1997; Wellman et al. 1997). Models that focus on these "fixed" ties are likely to overstate contagion effects and are bound to miss a good deal of the relevant network dynamics (Aral, Muchnik, and Sundararajan 2009; Shalizi and Thomas 2011) .

By the same token, the opposite strategy, focusing on relatively slow changing individual dispositions (such as deeply internalized values) in order to ascertain their effect on relatively faster changing relational events and states is also limited because only a small subset of relevant individual traits meet this theoretical criterion (Vaisey and Lizardo 2010). *The simplifying strategy of assuming either network stability or cultural and behavioral stability begs the fundamental question of how network dynamics and behavioral dynamics are interrelated, because these strategies settle the question of relative time scale ordering a priori rather than empirically.*

The Fundamental Science Questions

Addressing the question of how these two dynamic systems – the behavioral / cultural system and the social network system – are coupled is one of the most pressing issues in the behavioral and social sciences and will require a sustained interdisciplinary effort over a number of years. Substantively, there is a growing body of social science research that shows that some behaviors and traits (obesity, smoking, happiness, propensity to vote) apparently diffuse through social network ties (Bond et al. 2012; Christakis and Fowler 2007; Christakis and Fowler 2008; Fowler and Christakis 2008; Fowler and Christakis 2008; Lewis, Gonzalez, and Kaufman 2012; but see Cohen-Cole and Fletcher 2008; Cohen-Cole and Fletcher 2008). However, it is clear that not all behaviors, dispositions, tastes, and attitudes diffuse or are subject to contagion effects (in which case they might be implicated in the formation and decay of social ties). In the same way, it is clear that not all individual traits are equally relevant in accounting for dynamic changes in relational events and states, since individuals may think of certain traits (e.g. matching on political attitudes) as much more important for relationship maintenance than others (e.g. matching on their career aspirations).

Ascertaining what types of personal traits are more likely to diffuse through networks and thus be subject to contagion effects and what behaviors are less likely to diffuse and thus be likely to drive dynamic change at the relational level is critical to advancing our understanding of the role social networks can play in facilitating social and cultural change.

In order for a personal trait (taste, attitude, idea, disease) to diffuse across social ties, there must exist *durable* (e.g. relatively stable in relation to the trait) network connections between persons dissimilar on the trait in question. Social influence occurs as dissimilar agents become more similar *because of their social interactions*. Relational events (e.g. calling, having dinner, going out, and messaging) premised on the stability of the relational state (being friends) drives persons towards increasing similarity at the trait level (Homans 1950; Lazarsfeld and Robert K. Merton 1954). Personal traits align as the tie persists over time. However, there is also the possibility that agents decide not to change and instead decide to change either the pace of relational events (e.g. decrease the rate of interaction) or categorically change the relevant relational state (stop being friends). Personal traits may remain unchanged while the network changes (a tie decays). *In order to understand what behaviors and cultural traits are more likely to diffuse we need, therefore, to know which behavioral differences are more likely to lead to tie dissolution and therefore less diffusion, and which behaviors are more likely to change as a result of social interaction through tie persistence and interpersonal interaction.*

Methodologically, coupled dynamic systems pose difficult modeling challenges for behavioral and social scientists. The basic issue is how to isolate the different generative processes that lead to the observed network-trait matching (homophily). The problem is that there are a number of possibilities all of which are capable of generating the basic empirical result. Clustering on some trait (smoking, obesity, mental health, political attitudes) could be the result of (1) social influence (dissimilar people become more similar through their social interaction), (2) tie formation preferences and self-selection (people with certain predispositions seek out and form ties with similar others), (3) differential tie persistence (dissimilar social ties are more likely to decay), and (4) contextual effects causing spurious association between network ties and behavioral similarity (people sharing a context such as residing in the same area or being members of the same organization are both more likely to meet and form a social tie *and* more likely to develop similar behaviors). **Models for coupled dynamic systems must, therefore, not only include mechanisms through which behaviors can diffuse through social interaction, but also mechanisms specifying how (and when) social networks evolve through tie formation and decay.** In addition, mechanisms detailing how (and when) exogenous factors can affect both tie formation and behaviors must also be taken into account (Cohen-Cole and Fletcher 2008; Cohen-Cole and Fletcher 2008; Shalizi and Thomas 2011) .

Research Objectives, Questions and Approach

The two central goals of this proposed interdisciplinary research project are to:

(1) Develop, assess, and validate statistical and computational *models that can be used to understand the coupling between two dynamics systems* – the behavioral / cultural system and the social network system.
(2) Use these models to analyze *unique longitudinal data* that we have been collecting over the last few years that contains information on both network ties and individual trait changes in order to ascertain which traits are more or less likely to diffuse through networks.

We expect that via the application of better calibrated models to our unique longitudinal data set, we will be able to ascertain what types of personal traits are more likely to diffuse and what types are more likely to lead to endogenous network change. **Discoveries of this nature are critical to understanding how social networks evolve and the conditions under which they can facilitate positive social change.**

In Section II we discuss four models that are used in various disciplines in the sciences and the social sciences: cross-lagged models, separate evolution models, co-evolution models, and multi-level models with time-varying covariates. Development and assessment of dynamic network models has been hampered by the lack of longitudinal data on both social ties and behaviors (tastes and attitudes). The NetSense Project (which two of this project's PIs, Hachen and Lizardo, designed and conducted) has generated three years of repeated measured data both on network evolution and behavioral / cultural changes among ~190 college students (see Section III). As discussed in more detail in Section IV, initial analyses of this data reveals both change and stability in networks and behaviors, leading us to ponder under what conditions behaviors, tastes and attitudes change, under what conditions people's social networks change, and when behavioral / cultural changes lead to network changes and network changes to behavioral / cultural changes.

We are especially interested in five types of individual variables that past research has shown can and do change while students are in college: health (especially mental health), social and political attitudes, cultural tastes (e.g., musical genres and practices such as book reading and going to museums), aspirations (intended major, career choices) and specific behaviors / activities (drinking, playing video games, exercising, volunteering, being involved in politics). While we know that college is a time when students' behaviors, attitudes and tastes change, and while we also know that social ties with other students are very important in their social lives, there is very little research on how students' social networks co-evolve with their behaviors. Do students choose their friends based on how similar they are to them, and if so, which trait similarities are important in tie formation? Students meet and interact with many other students via various venues (classes, clubs, dining halls, dorms), but some of these ties "stick" while others never turn into durable friendships. What personal traits are more likely to lead to tie strengthening and persistence? How important are similarities in terms of gender, health, attitudes, and cultural tastes in tie evolution? Finally, people may not know about the traits of those they meet until after

they have interacted with them. As a result, people who think they are similar to others may discover differences and then the critical question is what happens to their social tie? Do people become more similar or do they decrease and maybe even stop interacting? Most importantly, are there some types of differences that are more likely to lead to tie dissolution, while other differences are more likely to disappear as interacting students become more similar?

Developing and using models for coupled dynamic systems in order to answer questions about the interrelationships between social networks and individual behavioral / cultural change requires an *interdisciplinary approach*. As discussed in Section VII, we have assembled a research team consisting of sociologists, a psychologist, a political scientist, a physicist and mathematician, and a computer scientist. The interdisciplinary composition of the research team will facilitate our research effort in four ways. First, the range of behaviors and attitudes we will study cut across the behavioral and social sciences (e.g. psychology, sociology, and political science). An interdisciplinary team with enhance our ability to share and integrate ideas from multiple disciplines about behaviors, attitudes and tastes that cannot be understood in isolation from one another and are embedded within social networks. Second, because diffusion occurs in many arenas of social life, our interdisciplinary effort will allow us examine whether diffusion mechanisms in one arena (e.g., political behavior) are similar to those in other areas (e.g., cultural tastes). Third, while the specific models and methods for understanding coupled dynamics systems have "grown up" within specific disciplines, an interdisciplinary effort is needed in order to develop and adapt these models so that we can see whether and what extent that are useful in other disciplines. Finally, as detailed in Section V, one of our central goals is to disseminate the tools and methods for understanding the dynamic coupling of social networks and behaviors across the behavioral and social sciences. Having researchers from different social science disciplines will allow us to understand the specific needs and challenges within each social science discipline and how our models and research can help scholars in that discipline advance their research agendas.

What is unique about our proposed interdisciplinary effort is that we will be studying human behavioral and cultural dynamics from a *social network perspective*. Social networks have always existed, but their importance in social life has grown in the last 50 years, in part because of new technologies. Technologies and applications such as the smartphone, SMS, Facebook, and email not only provide multiple ways in which people can communicate and interact with each other (Wellman 1983) but also generate temporally fine-grained data on who communicates with who, data that is beginning to be used by social scientists to map out and analyze social network dynamics (Eagle and Pentland 2006) .

Expected Project Significance

The key ***intellectual merit*** of our proposal is as follows:

- ***Enhancing the understanding of social networks as* dynamic *systems across the behavioral and social sciences***: By viewing social networks as dynamic systems that both evolve and potentially diffuse a wide range behaviors, we anticipate generating new findings about how social networks operate in a wide range of social arenas and the role networks play in individual and social change.
- ***Analysis of* longitudinal *data on both network ties and individual behaviors***: Using unique longitudinal data on both changes in network ties and individual behaviors will allow us to map out for the first time network evolution *and* individual level changes in behaviors and cultural traits over an extended period of time (2-4 years) in a systematic way.
- ***Developing and accessing* models *for coupled dynamic systems***: Dynamics is at the frontier of current research on all types of networks, including social networks. Advancing research at this frontier requires exploring the utility of different ways of modeling coupled dynamic systems. Four models for investigating how social networks and individual behaviors dynamics interact will be refined and used in order to develop predictions about network evolution and the diffusion of behavioral and cultural traits.
- ***Assessing the importance of social (interpersonal)* influence:** Through our models we will disentangle the various causal mechanisms that can lead to observed network-behavior matching (homophily) in order to ascertain how important social influence processes are in generating observed similarities among connected persons.

- ***Investigating a* wide range *of individual behaviors, attitudes, and tastes***: Current efforts focus on a limited set of individual outcomes in order to see if they diffuse through networks. Our interdisciplinary effort will allows us to examine a wide range of individual traits including psychological traits, health (including mental health), political and social attitudes, cultural affinities, social-psychological aspirations and expectations, and individual, social and political behaviors (drinking, smoking, playing video games, volunteering, activism).

The key ***broader impacts*** of our proposal are as follows:

- ***Promote and facilitate the use of* advanced tools, models and statistical methods *across the social sciences***: Standard methods in the social sciences are not appropriate for analyzing dynamic and complex (non-linear) systems like networks. The interdisciplinary project will refine and develop models and methods for analyzing dynamic systems, especially coupled dynamics systems involving social networks, and use various mechanisms (workshops, conferences, summer institutes) to broadly disseminate them throughout the behavioral and social sciences.
- ***Encourage and facilitate the collection by others of* longitudinal data *on social networks and behaviors:*** Our research will not only show why and how longitudinal data are critical to advancing our understanding of social networks, but also how others can collect such data using novel data collection methods that utilize communication technologies, and what types of longitudinal data are needed to address specific network evolution and diffusion questions.
- ***Provide* guidance on the appropriate models *researchers can use in their analysis of social networks****:*** By rigorously explicating the assumptions underling various models of coupled dynamic systems, researchers across the social sciences will have guidelines for choosing models that are most appropriate given the behaviors, cultural traits and network processes of interest to them within their specific discipline.
- ***Release of algorithms and statistical software:*** To facilitate future research on social network dynamics, we will release through various mechanisms our refinement of various statistical tools such that other researchers can use them to analyze their social networks.
- ***Stimulate research on what interventions could lead to* positive behavioral changes*:*** The ages during which people are in college are an important time when behavioral habits and dispositions form. Understanding which traits diffuse and which traits do not diffuse through social networks among people in this age group should help practitioners design interventions that facilitate healthy behaviors.
- ***Facilitate the* interdisciplinary training *of the next generation of computational social scientists:*** The social sciences are undergoing transformative changes as new sources of data, new methods for analyzing that data, innovative new ideas about how networks connect things, and new collaborations across disciplines emerge. For these transformations to take hold, the next generation of social scientists need to be exposed to the tools, conceptual frameworks, and cross-discipline research networks that they will need in order to understand, model, teach and creatively think about our social worlds and human behavior in them as networked dynamic systems. This project will do this in two ways: through graduate student and postdoc involvement in this interdisciplinary project and through various dissemination efforts.
- ***Understanding the specific ways in which social networks* facilitate social and cultural change*:*** Social networks matter. They can and do lead to social and cultural changes. But what is critical is how they lead to change – through changes within the network in who is connected to who and/or in changes in people's behaviors through their connections to others. Our research holds forth the promise of facilitating important social changes by increasing our understanding how social networks matter.

II. Modeling Coupled Dynamic Systems

The proper modeling of coupled dynamic systems has been an important, if still unresolved, issue for social scientists, physicists, mathematicians and statisticians. As noted in the recent NSF report *Rebuilding the Mosiac* (Gutmann and Friedlander 2011), new types of data in the social sciences and new ways of thinking about such data require new ways of modeling and analyzing data. As the 2009 report from Subcommittee on Social, Behavioral and Economic Sciences of the National Science and Technology Council (Weiss 2009) notes, this is especially the case with research on social networks

because individuals within networks cannot be viewed as independent entities and networked systems are complex dynamic systems with non-linear attributes.

To advance our ability to model coupled dynamic systems, we will rigorously investigate a number of modeling solutions that have been proposed and implemented for understanding dynamical systems and networks. Below we focus on four models. There are both methodological and substantive reasons for explicating and refining these models. Methodologically, some of these models are not strictly "network" models and have been used to model other types of dynamic systems. We will, therefore, modify and adapt these models so that they can be used to (1) analyze how social networks and cultural / behavioral systems are dynamically interconnected, and then (2) assess their utility by using them to model the co-evolution of a real network with a wide range of behaviors, attitudes, and tastes. While it could be the case that one of these models proves to be better for modeling the co-evolution of network and behaviors, we expect that the analysis is more likely to indicate under what conditions specific types of models are more (or less) appropriate. By rigorously specifying each model type and its core assumptions, researchers can then decide, given the type of behaviors and cultural traits that they are interested in and the kind of network dynamics that they observe which model is most appropriate.

Substantively, we will apply these models in order to predict which behaviors and cultural traits are more or less likely to diffuse in networks, and which ones are more likely to generate change in personal relationships (by fostering tie dissolution and maintenance). Special attention will be given to discrepancies between the models in their predictions. Of particular interest will be cases when some models identify a trait as diffusible while other models indicate that dissimilarities on that trait are more likely to lead to tie dissolution.

Cross-lagged (latent change score) models: These models are typically used to model the reciprocal effects of two individual level variables, x_{1i} and x_{2i} over time (McArdle et al. 2000; McArdle 2009). These models thus presuppose that the researcher has so-called panel data (data containing multiple observations for the same individual across time). We observe the values of the relevant person and network variables for a sample of individuals at 2 or more time points. Cross-lagged causal paths are specified $x_{1i}(t\text{-}1) \rightarrow$ latent change in x_{2i} (latent variable of $x_{2i}(t) - x_{2i}(t\text{-}1)$) and from $x_{2i}(t\text{-}1) \rightarrow$ latent change in x_{1i} (latent variable of $x_{1i}(t) – x_{1i}(t\text{-}1)$). Such models allow us to assess whether a latent change in x_2 from time t-1 to time t is a function of the value of x_1 at time t-1, *and* whether a latent change in x_1 is a function of the value of x_2 at time t-1. Extending this model to the interaction between network ties and individual traits could be done in two ways: $x_{1i}(t)$ could be an individual trait that both varies over time and across persons, while $x_{2i}(t)$ is an aggregate trait of a person's ego network, such as some measure of its composition (e.g., proportion of alters with liberal political orientations). The model would allow us to assess whether individuals with a given trait at time t-1 are more or less likely to experience change in the composition of their network on that trait, and whether the composition of a person's network at time t-1 predicts changes in a person's trait. Alternatively, the model could be applied with edges instead of nodes (person's) as the units of analysis. Under this specification, the two random variables that vary both across persons and across time are coupled dyad traits. The first dyadic trait indicates whether an edge is active at time t ($a_{ij}(t)$) (a relational state) or even the level of activity (strength) at time t (an aggregate of relational events), while the other dyadic trait is the similarity between the two vertices at time t on some individual behavior or attitude ($s_{ij}(t)$). A cross-lagged latent change score model would then allow us to assess whether the level of similarity/dissimilarity at time t between any two vertices predicts tie formation/decay and/or whether the presence/absence (or strength) of a tie at time t predicts changes in s_{ij}. The model with edges as the units of analysis is an extension of exponential random graph models (ERGM) as applied to edges (Robins et al. 2007; Robins et al. 2007; Snijders et al. 2006) in that it allows for the reciprocal effect of tie formation/decay on behavioral and cultural changes.

Independent Evolution Models: Here two separate dynamic models, one for diffusion of a behavior and one for network evolution are specified. Such models have recently been developed by physicists and epidemiologists interested in correctly estimating how long it will take for some disease to spread throughout a population and the disease immunization threshold. The problem with past models is that they assume a stable network upon which researchers model a dynamic diffusion process (though see Moody (2002)). Vespignani and his colleagues (Perra et al. 2012) recently developed a dynamic model that incorporates a dynamic network model (the activity model) with the susceptible infected-susceptible (SIS) contagion model. Their model of network dynamics, however, is extremely minimalist. For instance,

the model fails to take into account that ties can form or decay based on the infection status of the relevant nodes (thus it cannot accommodate trait effects on network evolution). Modifying their models to allow network dynamics to be a probabilistic function of vertex similarity would allow researchers to examine how and why agents form (or severe) ties in order to be (or not be) influenced (infected) by others.

Co-Evolutionary Models: In stochastic actor-based models tie formation and dissolution are viewed as stochastic processes shaped by both network structure (reciprocity, transitivity, degree) and individual traits (Burk, Steglich, and Snijders 2007; Snijders, Steglich, and Schweinberger 2007; Snijders, van de Bunt, and Steglich 2010). Markov chain models are used to model changes in the state of a network and statistical analysis is implemented through computer simulation in which the utility of various network configurations are estimated at each time point and used to determine whether an actor will dissolve, keep, or form a social tie (Snijders, van de Bunt, and Steglich 2010). The models have been adapted to allow for both changes in network ties and/or changes in personal traits, allowing researchers to assess how much of observed network-behavior matching is the result of choice homophily and how much is a function of social influence. These models make various assumptions about how and when both networks and persons can change.

Multi-Level Models (MLM) with Time-Invariant and Time-Varying Covariates. A trait of a tie such as its strength or existence can be viewed as varying across persons, across dyads, and across time. We denote the variable y_{ijk} where i indexes occasions (time), j edges (or alters), and k persons to reflect such features. y_{ijk} can be specified to be a function of (1) time-invariant person variables x_k such as gender, (2) time-varying person variables x_{ik} such as a behavior (3) time-invariant edge variables x_{jk} such as gender homophily, and (4) time-varying edge variables x_{ij} such as tie age and attitudinal/taste homophily. While these models are not network evolution models, they do allow the analyst to examine the correspondence between changes in traits (with time-varying covariates) and changes in the properties of network ties. This class of models can also be viewed as an extension of exponential random graph models (Robins et al. 2007; Snijders et al. 2006) and link prediction models (Clauset, Moore, and Newman 2008; Davis, Lichtenwalter, and Chawla 2011; Liben-Nowell and Kleinberg 2007; Lichtenwalter, Lussier, and Chawla 2010; Wang et al. 2011) that incorporate time in two ways: (1) modeling both between subject (or tie) *and* over time variation in some outcome and (2) including time-varying covariates (Rabe-Hesketh and Skrondal 2012; Raudenbush and Bryk 2002).

Agent Based Model (ABM) for Coupled Dynamic Systems

ABMs provide an experimentation framework, complementary to the statistical models designed for estimating parameters (Bonabeau 2002; Macal and North 2005; Nareyek 2001; Shoham and Leyton-Brown 2009). They are simulations that allow researchers to see whether specified micro (local) processes generate observed macro (global) properties of a system (network). We propose to develop a new model in which individuals are viewed as agents who can decide at each time step whether or not to change their behaviors or dissolve their ties with dissimilar alters, according to our assumptions or hypotheses inferred from interaction data. Our model will specify the rules that agents follow in making each of these decisions, and the tradeoffs between changing behaviors versus changing the persons with whom the agent interacts. The simulation can then ascertain what will happen to *both* the network and the composition of the population on the trait as a result of different propensities to dissolve dissimilar ties or change behaviors. For example, high proclivity to dissolve ties instead of change behaviors could lead to the dissolution of a network's giant component, while high proclivities to change behaviors could lead to population homogeneity. Model results would then be compared to observed combinations of population heterogeneity and network connectedness. Varying the parameter related to how agents weigh the tradeoff between changing behavior and dissolving ties will allow us to map the parameter space that yields realistic network configurations and population composition levels. Observed network configurations and population compositions can then be compared to model results, allowing us to link parameter values to these two outcomes. In this way we will ascertain through a generative model, which traits are more likely to diffuse and which traits are more likely to lead to tie dissolution when agents are dissimilar on them.

III. Data: The NetSense Study

Until recently most social network studies gathered network data through surveys in which respondents are asked about the people with whom they interact. The increasing use of digital forms of communication made possible by new technologies make it possible to unobtrusively collect more reliable behavioral network data through the electronic logging of communication events. In the Fall of 2011 we launched the NetSense Project funded by a NSF Social-Computational Systems (SoCS) grant in which we use smartphones to collect behavioral social network data from 190 first-year college students who had just entered the University of Notre Dame (ND). In cooperation with Sprint, students received a high quality smartphone and a free voice/text/data plan to use for two years. We developed an application that captures information on all communicative interactions through the phone such as the phone numbers of the sender and receiver, time and date, duration, and type of event (text message, voice call, email), and then securely sends that information to a server for storage. The content of communications is never captured. Additionally we developed an application that allows us to detect when two phones are in physical proximity using Bluetooth detection (Liu and Striegel 2011), and we obtained permission from subjects to gather information from Facebook posts on who posted on their Facebook pages. As a result we have a temporally fine-grained record of our subject's social ties based on multiple indicators of interaction – voice calls, texts, emails, co-presence and Facebook postings. To date our main focus has been on ties identified by voice calls and texting. Among the 161 students who continued in the study for 107 weeks, we have information on ~60 million communication events occurring within ~55,000 ties of which almost half entail mutual interactions (A called/texted B and B called/texted A). Though the NSF-funded project terminated in the Spring of 2013, we secured funding from Sprint to continue the study with new smartphones and free plans for another two years. ~100 students chose to continue, so for them we will have a full 4 years of data. We also recruited ~40 new subjects who are friends of the continuing students.

The behavioral network data are supplemented by survey data. Two web surveys were administered to students prior to their arrival on campus – a network survey in which subjects were asked about the 20 people with whom they had interacted, and a general survey through which we obtained information on each subjects' demographic traits, background, high school activities, personality, physical health, mental health, aspirations, social and political attitudes and cultural practices (e.g., the types of music they like). In the network survey, subjects were asked to provide us with the phone numbers of the people they mentioned, allowing us to match information they gave us on these people to the communication records obtained through their smartphones. Both the general survey and the network survey have been repeated every 3-4 months using similar questions, yielding to date seven waves of data.

The network survey is especially valuable for identifying who are the people (alters) with whom our subjects (egos) communicated. ~1300 of the 25,000 mutual ties are between two NetSense subjects, and for these ties we have a great deal of information about both the ego and the alter. However the vast majority of interactions are with non-NetSense participants, and we only have information on them if a participant also mentioned them in a network survey. With information from the network surveys were are able to classify over 60% of these ties as either family ties, non-family ties they had prior to arriving at Notre Dame, and post-arrival ND ties It is this latter type of tie that is of special interest because all subjects began with no such ties and therefore we can see how their networks evolve through tie formation, decay and strengthening. The network surveys also provide us with information on a person's alters, such as their gender, race/ethnicity, and our subject's subjective assessment of the closeness of the tie, how similar they are to each alter, and the ties among the alters that they named.

IV. Results from Prior NSF Support

A. Explorations on the Effects of Pervasive Networking on Social Relationships and Resource Planning : The PI (Hachen), co-PI (Lizardo) and Faculty Associate (Striegel) have collaborated on the NetSense Project study funded by the NSF. A general overview of the study is reported in Striegel et al. (2013). Analysis to date has focused mostly on network evolution. Our initial analysis of the data gathered through this project was on the 514 ties (defined in terms of voice calls and text messages) formed between 183 subjects during the first 45 weeks of the study. We mapped the evolution of the network with a focus on within versus between dorm ties (see Figure 1). We found that within dorm ties

tended to be more heterophilous on a number of traits such as parent's religion, income, and education and the student's ethnicity. Choice homophily (forming ties with similar others) is more prevalent with ties to students residing in other dorms (Hachen, D., Lizardo, O. Penta, M. Crubaugh, B. 2012) .

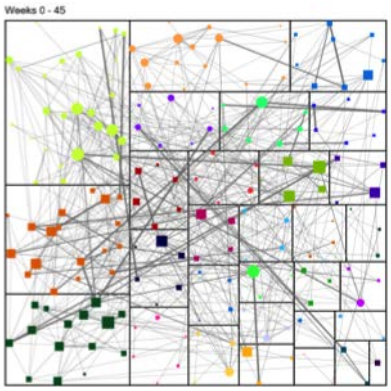

Figure 1: Communication ties among students within and between dorms (color – dorm, squares – males, circles – females, size of node – degree, line thickness/opacity – interaction frequency

In a more expanded analysis we looked at how the size of each student's network grew through the first academic year (Hachen and Lizardo 2013; Hachen 2013). While the typical student in our sample interacts with about 50 students by week 39 (the end of their second semester), at any point in time their effective network size (degree) is about 25 and their active degree in a given week is about 11. Most students reach their effective degree within the first 13 weeks. After that their degree is fairly stable. While the average degree across subjects is around 25, there is a good deal of variation. This variation is highly correlated with one personality trait, extroversion. A one unit increase in extroversion (on a 5 point scale) is associated with ~7 more ND friends. Analysis also indicates that while women have about 4 more ND friends in the first semester, by the end of the second semester this gender gap is reduced to 2.

While these analyses identify ties in terms of voice and text communications between two persons, as noted earlier we also have co-presence, Facebook and email data. Using this data, Striegel working with colleagues constructed adjacency matrixes describing the presence/absence of a tie among 150 active NetSense participants during the first 18 months of the study (Meng, Milenkovic, and Striegel 2013). They then examined the association between these different representations of the network and found that SMS and proximity representations are highly associated.

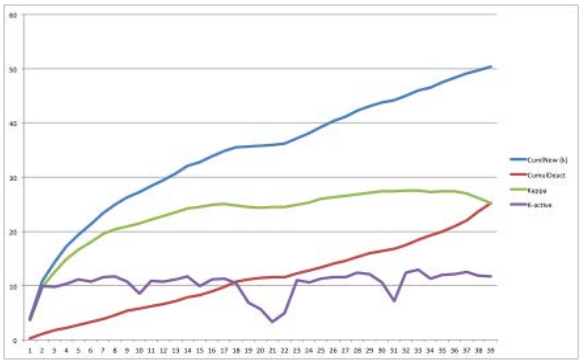

Figure 2: Weekly average values of cumulative degree (blue), effective degree (green), active degree (purple), and cumulative count of deactivated ties (red).

Working with a former graduate student who worked on this project, we have begun to examine the co-evolution of the network and a range of behaviors using a Siena model. Two behaviors have been investigated, alcohol consumption and political orientation. The findings for drinking indicate that social influence is occurring in this this sample (Wang, Hachen, and Lizardo 2013). Students who had higher or lower drinking levels than their alter tended to be pulled in the direction of their alter's behavior. However some of the network-behavior matching on drinking is not due to social influence but to selection processes in which students formed ties to those with similar drinking levels to theirs, though the influence mechanism appears to be more important for this behavior than selection. The findings are different for political orientation. For this disposition, we detect a selection effect but not an influence effect. This preliminary work confirms our expectation that some traits are more likely to diffuse, while other traits are more likely to lead to tie formation (when similar) and tie dissolution (when dissimilar). One of the central objectives of our proposed research is to identify which traits fall in which category, and to develop a better understanding of why some traits diffuse through networks while other traits are related to tie existence and decay.

SoCS: Explorations on the Effects of Pervasive Networking on Social Relationships and Resource Planning, CBET 09-68529, Hachen, Striegel, Lizardo, Poellabauer (PIs) $764,825, 2010-2013

Synopsis: Two hundred entering college students were given a smartphone and free plans for two years in order to capture their communication behavior (not content) and map out their social networks. Periodic surveys were used to gather information on tastes, attitudes and behaviors.

Analysis involves mapping out and explaining the evolution of their social networks, predicting variation in the size and growth patterns within networks, and modeling the influence of social ties on individual behaviors and attitudes.
Intellectual Merit: The technical aspects of the project involving the development and updating of a monitoring app, developing a reliable system for detecting when two phones are near each other (Liu and Striegel 2011; Liu and Striegel 2012) and maintenance of a database from streaming communication data have advanced our ability to create a reliable and scalable system for using smartphones to gather communication network data. The sociological research has revealed a great deal about social network evolution and tie characteristics (Hachen, D., Lizardo, O. Penta, M. Crubaugh, B. 2012; Hachen and Lizardo 2013; Hachen 2013; Wang, Hachen, and Lizardo 2013; see discussion above).
Broader Impact: The interdisciplinary collaboration between social scientists and computer scientists and engineers enhanced our ability to develop and modify technical systems so that they can capture unobtrusively traces of behaviors. The wealth of longitudinal data on both changes in people's social ties and their tastes/behaviors will facilitate our understanding of (1) network dynamics and (2) the various processes that play a role in observed network-behavior matching.

B. Longitudinal Analysis and Modeling of Large-Scale Social Networks Based on Cell Phone Records: In an earlier project, Hachen, Lizardo and Toroczkai with others analyzed a large communication network among 7 million cell phone subscribers over a two month time period. The focus was on network evolution and the development of a general model of tie formation and persistence that could account for the macro patterns we observed in the data, in particular degree assortativity, the tendency for nodes of a similar size to have ties. These data indicate that newly formed ties tend to not survive very long (the liability of newness), so a critical research question is why do some ties persist while most die early on? Because we also know how frequently two people communicated with each other and who initiated each communication event, we were able to look at tie strength and develop new measures of tie reciprocity. Using machine learning algorithms, we found that while stronger ties are more likely to survive (as expected), weaker ties can also survey if they are reciprocal (Raeder et al. 2011). We postulated that ties evolve from weaker to stronger if they become more reciprocal, but if they do not they are likely to disappear. In subsequent work (Wang et al. 2012) we looked at levels of non-reciprocity in this communication network in order to evaluate two explanations for it: (1) the prevalence of dissassortivity (i.e. ties between higher and lower degree nodes) and (2) non-equidispersion of interactions (an ego interacts with some of her alters more than others). We assess the veracity of each explanation by rewiring the observed social networks to remove degree assortativity and/or constraining the ties each person has to have equal weight, and then calculate levels of non-reciprocity in the network. Results indicate that both non-equidispersion and degree assortativity account for some non-reciprocity, but that non-equidisperion is a more important factor. As a result of this analysis we built an agent base model to see if we could generate macro (network) properties, especially degree assortativity, from one micro (local) level process (rule): persons are more likely to stop interacting with an alter if the tie is non-reciprocal (i.e. they initiate interaction more with their alter than their alter does with them). Results indicate that that this simple one parameter model can generate not just the levels of degree assortativity that we observe in our real network, but many other important network properties (Strathman and et al 2012).

Finally, with these data we have been examining triadic evolution, that is the formation of triangles (ties between all three nodes in a triad) from two-paths (a configuration in which an edge is missing between two of the three nodes in a triad), and the dissolution of triangles. In this work, based on the dissertation research of our former graduate student Cheng Wang, we find that dyadic processes related to tie strength, reciprocity and assortativity are very important in predicting both triangle formation and dissolution, but that lower-level (node) and higher-level (embededness of edges) are also important (Wang 2012).

DHB: Longitudinal Analysis and Modeling of Large-Scale Social Networks Based on Cell Phone Records, BCS-0826958, Hachen, Lizardo, Alber, Chawla (PIs), $711,770, 2008-2012
Synopsis: The growth in information technology systems is generating new sources of data on

human behavior that are only now beginning to be analyzed. Digital communications systems can log communication events and therefore contain valuable information on usage patterns that can be used to map social networks and analyze human behaviors within them. This project developed 1) novel computational and analytic approaches to both cross-sectional and longitudinal social network data analysis, based on advanced nonlinear time-series methods, community detection algorithms, and probabilistic relational models (data mining); 2) stochastic mathematical models for network behavior coupled across several levels of analysis, including node, dyad, triad and group levels and 3) a data-driven stochastic individual–based simulation (SIBS) framework suite for social network dynamics. (Raeder et al. 2011; Wang et al. 2012; Wang et al. August 2011)
Intellectual Merit: The project made major contributions by (1) advancing longitudinal social network data analysis tools, (2) identifying and modeling novel mechanisms and theories pertaining to tie formation and tie decay (Davis, Lichtenwalter, and Chawla 2013; Lichtenwalter and Chawla 2011; Lichtenwalter, Lussier, and Chawla 2010; Lichtenwalter and Chawla 2011; Steinhaeuser and Chawla 2010) , (3) using weighted edge data to develop a new measure of reciprocity (Raeder et al. 2011; Wang et al. 2012), and (4) conducting a data-driven agent-based model simulation that showed how local processes generate global network properties.
Broader Impact: The interdisciplinary collaboration between social scientists, computer scientists, physicists, biologists and mathematicians facilitated the diffusion of key ideas and tools from both science and engineering into the social sciences, and from the social sciences into the sciences. The research brought to the fore the importance of looking at the evolution of networks, and in particular tie persistence and the role that reciprocity plays in persistence. It also focused attention on how social networks differ from other types of networks that do no have reciprocity and degree assortativity.

***C. MRI: Acquisition of a Data Analytics Cluster for Computational Social Science*:** Hachen is a co-PI on a recent NSF equipment grant through the Center for Research Computing (CRC) at the University of Notre Dame. This grant created a state-of-the-art social science computational cluster in the CRC that will be used in this project.

MRI: Acquisition of a Data Analytics Cluster for Computational Social Science, 1229450, Nabrzyski, Chawla, Hachen, Lubke, Mark PIs, $711,770, 2012-2015
Synopsis: Purchase, installation and training for Data Analytics Cluster for Computational Social Sciences (DACCSS). Provides computational social scientists with over 2,600 CPU cores, 5,300 GB of RAM, and 60TB of high performance storage in 42 clustered data analytics servers connected with a state of the art Infiniband network fabric running the world's most advanced analytics software applications
Intellectual Merit: This project has enabled transformative research in the social sciences through the acquisition of a DACCSS. The major capabilities provided by DACCSS are accelerating existing computational social science (CSS) research that has been throttled by insufficient computational capability, enabling analysis and discovery at scales previously inaccessible, incubating new research projects and enhancing multidisciplinary collaboration between social scientists and their peers.
Broader Impact: The emergence of CSS requires the development of a paradigm for training new social science scholars; the DACCSS operation and training management plan will have direct integration with a CSS training plan for faculty, post doctoral researchers and students of sufficient rigor to share with peer universities. This facility will also help build stronger bridges between social science, computer science and applied math through regular dialog of faculty from each discipline centered around novel and effective DACCSS utilization.

V. Proposed Research

There are two phases to our proposed research project, the research phase and the dissemination phase. Years 1 & 2 will involve intensive model development, statistical analysis, network visualization, and simulations. The objectives for this period are to:

1) Develop useful and instructive descriptions (including visual depictions) of how the ND student network evolved over two years along a range of dimensions such as tie formation and dissolution; tie strength; reciprocity; network clustering (transitivity); and network-trait matching along various dimensions such as gender, race/ethnicity, predispositions, within vs. between dorm ties. We will also identify the temporal patterns of network evolution, that is when ties are more likely to form and when they are more likely to be deactivated.
2) Compare the network evolution patterns identified through text, voice, email, Facebook, and face-to-face communication modalities.
3) Map out the patterns of change in a range of social and political attitudes, aspirations, activities, health, cultural tastes and behaviors / activities and demographic differences (gender, race/ethnicity) in these patterns. Assess the temporal patterns of changes.
4) Develop and refine the four basic models discussed in Section II that we will use to test hypotheses about what traits are more likely to diffuse and what traits are more likely to lead to tie dissolution. Clarify each model's assumptions and limitations. Identify and adapt software to our special situation of network analysis.
5) Use each model to (a) determine what exogenous factors are more important predictors of network evolution and behavioral changes, and most importantly (b) assess the extent to which selection and/or influence processes are at work and (c) identify which traits are more likely to diffuse and which traits are more likely to lead to tie dissolution.
6) Develop an ABM and conduct simulations in order to identify how the tradeoff between becoming more similar or dissolving a tie generates macro network patterns and population compositions along a range of dimensions. Use these simulations to help identify diffusible traits by comparing simulation results to observed network and population properties.

One of the goals of this project is to disseminate the results of this research in order to stimulate longitudinal research on the coupling of network evolution and behavioral change. We hope that this endeavor will encourage (1) the collection of longitudinal network and behavior data by social scientists and (2) the use of methods and models for analyzing complex dynamic systems. The dissemination effort will take place in Year 3 and will be more extensive than the normal presentation of papers at conferences and publication of findings. There will be two aspects to this dissemination effort. First, we will develop a "curriculum" consisting of tools, workshops, demonstrations, courses, slides, videos, and instructional materials that our research team and others can us to educate others about network dynamics, how to model social influence, diffusion and network evolution processes, and how to collect network and behavioral data. These materials can then be used by members of our research team to conduct workshops and mini-courses at conferences like the annual International Network for Social Network Analysis Sunbelt Conferences and International School and Conference on Network Science, and at summer institutes like those held at the Interuniversity Consortium for Political and Social Research. We will also hold in the Summer of 2017 a Summer Institute at the Interdisciplinary Center for Network Science and Applications at the University of Notre Dame. Second, we will hold a small conference in the Spring of 2017 at Notre Dame on social networks as dynamic systems. While the conference will have the usual invited speakers, presentations and poster sessions, we will also conduct demonstrations and workshops using the "curriculum" that we have developed.

VI. Management Plan

The project team will consist of six persons, two sociologists (David Hachen and Omar Lizardo), a political scientist (David Nickerson), a quantitative psychologist (Lijuan (Peggy) Wang), a physicist / mathematician (Zoltan Toroczkai), and a computer scientist (Aaron Striegel). Hachen will be the project manager and the person responsible for reports and ensuring compliance with research protocols. Hachen, Lizardo and Striegel currently work together on the interdisciplinary NetSense project, and Hachen, Lizardo and Toroczkai worked together on the NSF Longitudinal Analysis Project. Hachen and Toroczkai are co-directors of iCeNSA and Lizardo is a faculty affiliate. As a result the majority of this team has a long history of working together on collaborative projects and a great deal of experience in managing and coordinating efforts of a large team of faculty, graduate students, post-docs and staff. In this project there will be four graduate student assistants (one each in psychology, sociology, political science, and computer science) and two post-doctoral fellows (one in physics and one in a social science discipline).

Over the years we have found that a sub-project structure works very well with bi-weekly meetings of the whole team alternating with bi-weekly meetings of specialized teams focused on specific projects that are being worked on at that time. The character of the specialized teams will evolve over time as specific projects become important and then are completed. At the outset we envision three teams: a group focusing on developing models including the ABM, a group focused on describing and visualizing network evolution, and a group focused on describing changes in behaviors, attitudes and changes. After the first half of a year, the groups will be reorganized around modeling the coupled dynamics between changes in networks and changes in behaviors and cultural traits, with specific teams focusing on specific sets of behaviors, attitudes and cultural tastes. The bi-weekly general meeting will be used to coordinate research efforts, share results emerging from each of teams, and formulate new research projects. The bi-weekly specialized team meetings will focus on showing to the full team the results of each team member's work, discussing findings, and formulating and assigning tasks. During the second "curriculum development" phase of the project the team structure will change again. Specific teams will be in charge of developing specific curriculum items, and general team meetings will involve planning ways to disseminate our work including the proposed conference and summer institute.

Though this project does not involve data collection (the data have already been collected, though some collection will still occur in 2014-2015 through the NetSense project), the already collected data need to be managed, and the distribution of data to team members needs to be monitored and secured. Currently all communication event data and survey data are maintained on secure servers housed at the Center for Research Computing. Aaron Striegel (NetSense Project PI) and his students have developed a highly secure system for maintaining the large amounts of data and limiting those who are able to access these data. Not all researchers will have direct access to these confidential data. Instead Striegel and his graduate research assistant, as well as one or two other graduate students and/or post-docs on the project who have been trained by Striegel, will have direct access allowing them to create extracts that other members of the team need. All researchers involved on this project, including senior personnel, postdocs and graduate students, will be required to complete "The Collaborative Institutional Training Initiative" online courses so that they are familiar with the ethical issues surrounding human subjects research and the methods used to maintain the confidentiality of data collected from human subjects.

In the past we have employed a Wiki to keep track of research projects, initiatives, requests from outside, problems and issues. We plan to migrate from a Wiki system to using Google Drive or Box to keep adequate records of project activities as these systems allow all team members to add material, comment, and assign tasks.

Travel funds will be equally divided among the PIs, with a portion of the funds reserved for professional development of the post-docs in each year. At the end of each reporting year, all teams that have been active in the year will be responsible for collating together materials needed for annual reports. All PIs will have on-line access to the budget and will be responsible for monitoring allocations for personnel for whom they are responsible (graduate students, their post-doc).

VII. Interdisciplinary Character of Project

This project is a highly interdisciplinary project bringing together not only researchers from three different social science disciplines (Sociology, Psychology and Political Science) but also researchers from the social sciences, the sciences, and engineering. Hachen, Lizardo, Toroczkai, and Striegel have extensive experience conducting interdisciplinary research, and Hachen and Toroczkai, as co-founders of iCeNSA with Nitesh Chawla, have been at the forefront of interdisciplinary research at the University of Notre Dame.

As noted in recent reports from NSF and the National Science and Technology Council (Gutmann and Friedlander 2011; Weiss 2009), network science is at its core an interdisciplinary field that is experiencing rapid growth. Networks are evident in virtually all research fields: biology, neuroscience, engineering, physics, and across the social sciences in sociology, political science, economics, psychology and anthropology. Over the years we have found that cross-discipline collaborations on networks can be especially useful as they allow for field specific findings, ideas, models, methods and innovations to spread to other fields and stimulate new ways of thinking about and doing research on networks within a field. In the specific case of social networks, the focus of this project, the behaviors,

attitudes and tastes that can diffuse through networks and affect network evolution cut across the social science disciplines. If we are to better understand what behaviors are more likely to diffuse and which ones are important in network evolution, then we need to consider the full range of behaviors and traits including psychological traits, health (including mental health), political and social attitudes, cultural affinities, social-psychological aspirations and expectations, and individual, social and political behaviors (drinking, smoking, playing video games, volunteering, activism).

Methodologically, the underlying core of network science derives from graph theory in mathematics and statistical mechanics in physics (for understanding the dynamics and emergent properties of complex systems). However the methods for describing, depicting, modeling and predicting network evolution and diffusion are coming from many fields including statistics, computer science (machine learning), epidemiology, systems biology, econometrics, psychometrics and sociology. Tools that have been developed for studying behavior change and individual level outcomes such as longitudinal panel data analysis or multi-level modeling are being adapted and used to study network evolution, and statisticians have developed tools specifically for network analysis such as ERGMs and stochastic actor-based models. Our team not only contains members with expertise pertaining to many of these methods, but it is our expectation that through working together each of us will increase the repertoire of methodological tools at our disposal for doing network research in our specific field. The workshops and dissemination efforts in Year 3 are designed to diffuse the network methods and ideas we will develop beyond our team into the various social science disciplines.

The team for this project brings together people with a wide array of interests and expertise pertaining to networks in general, and social networks in particular. Hachen brings to this project expertise on social networks focusing on (1) directional weighted networks that allow modeling of tie strength and reciprocity, (2) tie evolution and the role reciprocity plays, (3) how micro interaction processes generate macro network properties and (4) when and how social influence occurs. Lizardo a cultural and theoretical sociologist brings to the project expertise on cultural practices, and a strong theoretical interest in the micro-foundations or macro phenomena and linking theory to mathematical models. Nickerson, a political science experimentalist and methodologist, work on political mobilization has led him to investigate the role that social networks play in diffusing political campaigns and recruitment. Wang, a quantitative psychologist and expert on longitudinal data analysis and multi-level modeling brings to the project an interest in using advanced quantitative methods to model changes in health, especially mental health, and how network changes interact with changes in health. Toroczkai, a theoretical physicist and mathematician is one of the preeminent network science researchers whose expertise in agent based models, non-linear dynamics, and complex systems has informed research not just on social networks, but also on cerebral cortical connectivity and communication networks. Striegel, a computer scientist and engineer, brings to the project expertise on wireless networks, network security and network visualization.

Interdisciplinary research creates opportunities for translational innovations and discoveries but poses challenges as well. Since four of us have extensive experience working together on interdisciplinary projects, we are well aware of these challenges, which often have to do with coordination across different disciplines and developing a common language. We have found that it is critical in large interdisciplinary projects to facilitate both discipline specific research *and* the sharing of ideas across disciplines. Members of our team bring to the project different research interests and agendas, and the projects success depends also on their ability to pursue their field specific interests. We have found that the two critical benefits of interdisciplinary work are (1) the diffusion of ideas across disciplines which helps research within that may event lead to novel methods and (2) the cumulative growth in general knowledge, methods and theories, in our case about networks, that can inform future research in many disciplines across the social sciences, science and engineering.

VIII. Conclusion

As the numerous white papers that form the basis for NSF's *Rebuilding the Mosaic* (Gutmann and Friedlander 2011) report indicate, the behavioral and social sciences are undergoing profound transformations as a result of new sources of data, new ideas and concepts, new methods and research tools, new ways of thinking about behavioral and social phenomena as dynamic systems, and new forms of social organization for doing research. In turn, these profound changes are allowing researchers to explore topics and make discoveries that would not have been possible 20 years ago. Perhaps the best

example of this is the growing research on networks of all kinds, but especially research on social networks. The old static paradigm in which behavioral and social systems were viewed as relatively simple, stable structures is giving way to a view of these systems as complex, dynamic, non-linear, distributed, networked entities.

Our proposed project is both part of this fundamental shift in the behavioral and social sciences *and* an initiative to advance these changes in the behavioral and social sciences. As a result of the NetSense project, we have at our disposal high quality longitudinal social network data derived from the electronic logs of people's communication activity. These data are forcing us to think about social networks and human behavior in new ways, as coupled dynamic systems in which social networks and behaviors co-evolve. In order to model and analyze these data, we need to refine and develop models and methods for analyzing coupled dynamic systems. Both doing this research and disseminating our findings will require an interdisciplinary, collaborative form of social organization that facilitates exploring changes in a wide range of behaviors and individual traits using a wide range of models and methods. Together new data, new ideas, new models and methods, new ways of thinking, and an interdisciplinary form of social organization will allow this project to address one of the most fundamental science questions in the behavioral and social sciences: what personal behaviors and cultural traits are more likely to diffuse through networks and which ones are less likely to diffuse and thus more likely to drive dynamic network change?

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Steinhaeuser, Karsten and Nitesh V. Chawla. 2010. "Identifying and Evaluating Community Structure in Complex Networks." *Pattern Recognition Letters* 31:413-21.

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Wimmer, Andreas and Kevin Lewis. 2010. "Beyond and Below Racial Homophily: ERG Models of a Friendship Network Documented on Facebook1." *American Journal of Sociology* 116:583-642.

Curriculum Vitae (12.1.13)

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(a) Professional Preparation:

- Major in political science and philosophy, Lake Forest College, 1970-1974
- MA. in Philosophy, University of Wisconsin-Madison, 1978
- Ph.D. in Sociology, University of Wisconsin-Madison, 1983

(b) Appointments:

- Associate Professor of Sociology, University of Notre Dame, 1993-present
- Assistant Professor of Sociology, University of Notre Dame, 1988-1993
- Visiting Assistant Professor of Sociology, University of Notre Dame, 1987-1988
- Assistant Professor of Sociology, University of Washington, 1983-1987
- Research Assistant, Institute for Research on Poverty, University of Wisconsin, Madison, 1979 to 1983.
- Assistant to the Editor, *Politics and Society*, University of Wisconsin-Madison, 1978 to 1981.

(c) Products

i. Products (5) Related to the Project

Wang, C., Hachen, D. S., and Lizardo, O. 2013. "The Coevolution of Communication Networks and Drinking Behaviors. *2013 AAAI Fall Symposium Series: Social Networks and Social Contagion*, 30-36.

Striegel A., Liu S., Meng, L., Poellabauer, C. , Hachen, D , and Lizardo, O. 2013 . "Lessons learned from the Netsense smartphone study," *Proceedings of ACM HotPlanet (workshop at ACM SIGCOMM),* Hong Kong , 51–56. **Best Paper Award**

Wang, C., Lizardo, O, Hachen, D., Strathman, A., Toroczkai, Z., Chawla, N. 2013. "A dyadic reciprocity index for repeated interaction networks," *Network Science* 1(1):31-48.

Troy Raeder, Omar Lizardo, Nitesh V. Chawla and David Hachen. 2011. **"**Predictors of Short-Term Decay of Cell Phone Contacts in a Large Scale Communication Network." *Social Networks*. 33 (4):245-257

Hachen, D. and Davern, M. 2006. "The Role of Information and Influence in Social Networks: Examining the Association Between Social Network Structure and Job Mobility." *American Journal of Economics and Sociology*. 65 (2):269-293

ii. Other Significant Products:

Zhi Zhai, Tracy Kijewski-Correa, Ashan Kareem, David Hachen, Greg Madey. 2012. "Citizen Engineering: Evolving OSS Practices to Engineering Design and Analysis." 8th International Conference on Open Source Systems, (OSS2012), Hammamet, Tunisia.

Zhi Zhai, Tracy Kijewski-Correa, David Hachen and Greg Madey. 2012. "Haiti Earthquake Photo Tagging: Lessons on Crowdsourcing In-Depth Image Classifications." Seventh IEEE International Conference on Digital Information Management, ICDIM 2012, Macau, China, August 22-24, 2012. IEEE 2012, ISBN 978-1-4577-1538-9.

Zhai, Z., Hachen, D., Kijewski-Correa, T. Shen, F. and Madey, G. 2012. "Citizen Engineering: Methods for 'Crowdsourcing' Highly Trustworthy Results," *Proceedings 45th Hawaii International Conference on System Sciences*, January 4-7, Maui, Hawaii: 3406-3415.

Hachen, David (co-authored with Gregory R. Madey, Albert-László Barabási, Nitesh V. Chawla, Marta Gonzalez, Brett Lantz, Alec Pawling, Timothy Schoenharl, Gábor Szabó, Pu Wang and Ping Yan). 2007. Enhanced Situational Awareness: Application of DDDAS Concepts to Emergency and Disaster Management" in International Conference on Computational Science, serial Lecture Notes in Computer Science (LNCS 4487), Y. Shi, G. D. van Albada, J. Dongarra, and P. M. A. Sloot, Eds.:1090-1097

Hachen, David and Brian Conway. 2005. "Attachments, Grievances, Resources, and Efficacy: The Determinants of Tenant Association Participation Among Public Housing Tenants." *Journal of Urban Affairs.* 27 (1):25-52

(d) Synergistic Activities:

- Co-Director, Inter-Disciplinary Center for Network Science and Applications, University of Notre Dame, 2008-present
- Course Management Systems Steering Committee, 2005-2008
- Fellow, Institute for Education Initiatives, University of Notre Dame, 2000-present
- Faculty Affiliate, Higgins Labor Research Center, University of Notre Dame, 2000-present

Collaborators and Other Affiliations

i. Collaborators and Co-Editors (past 48 months)

- Dr. Nitesh Chawla, University of Notre Dame
- Dr. Zoltan Toroczkai, Univeristy of Notre Dame
- Dr. Omar Lizardo, University of Notre Dame
- Dr. Tracy Kijewski-Correa, University of Notre Dame
- Dr. Gregory Madey, University of Notre Dame
- Dr. Cheng Wang, University of California-Irvine

ii. Graduate Advisors and Postdoctoral Sponsors

Erik Olin Wright, University of Wisconsin-Madison

iii. Thesis Advisor and Postgraduate-Scholar Sponsor (past five years)

Thomas Burkemper, Ph.D., Annheuser Busch Co.
Michael Davern, Ph.D., University of Minnesota
Jay R. Howard, Ph.D., Dean – Liberal Arts and Sciences, Butler University
Ana L. Rodriguez-Gusta, Ph.D., Universidad Nacional de San Martin, Argentina
Cheng Wang, Ph.D., Post-Doctoral Fellow, Univerisity of California-Irvine

Total number of graduate students advised: 5

BIOGRAPHICAL SKETCH
OmarLizardo

a. Professional Preparation.

Institution	Major	Degree	Year
Brooklyn College (CUNY), Brooklyn, NY	Psychology	B.S.	1997
University of Arizona, Tucson, AZ	Sociology	Ph.D.	2006

b. Appointments.

2012-present	Associate Professor, Department of Sociology, University of Notre Dame, Notre Dame, IN.
2006-2012	Assistant Professor, Department of Sociology, University of Notre Dame, Notre Dame, IN.
2003-2006	Instructor, Department of Sociology, University of Arizona, Tucson, AZ
2000-2006	Research Assistant, Department of Sociology University of Arizona, Tucson, AZ

c. Products.

PRODUCTS MOST CLOSELY RELATED

[1] Cheng Wang, **Omar Lizardo**, David Hachen, Anthony Strathman, Zoltán Toroczkai, and Nitesh V. Chawla. 2013. "A dyadic reciprocity index for repeated interaction networks." *Network Science* 1: 31-48.

[2] **Omar Lizardo**. 2013. "Variety in cultural choice and the activation of social ties." *Social Science Research* 42: 321–330.

[3] **Omar Lizardo.** 2011. "Cultural correlates of ego-network closure." *Sociological Perspectives* 54: 479-48**.**

[4] Troy Raeder, **Omar Lizardo**, David Hachen and Nitesh V. Chawla. 2011. "Predictors of short-term decay of cell phone contacts in a large scale communication network." *Social Networks* 33: 245-257.

[5] Stephen Vaisey and **Omar Lizardo**. 2010. "Can cultural worldviews influence network composition?" *Social Forces* 88: 1595-1618.

OTHER SIGNIFICANT PRODUCTS

[1] **Omar Lizardo** and Melissa Fletcher Pirkey. 2012."How organizational theory can help network theorizing: Linking structure and dynamics via cross-level analogies." Research in the Sociology of Organizations (forthcoming).

[2] Omar Lizardo and Jessica Collett. 2013. "Embarrassment and social organization: A multiple identities model." *Social Forces* (in press).

[3] Robert Fishman and **Omar Lizardo**. 2013. "How Legacies of macro-political transformation shape patterns of cultural taste: Portugal and Spain in comparative perspective." *American Sociological* Review 78: 213-223.

[4] **Omar Lizardo** and Sara Skiles. 2012. "Reconceptualizing and theorizing 'omnivorousness': Genetic and relational mechanisms." *Sociological Theory* 30: 260-280.

[5] Jessica Collett and **Omar Lizardo**. 2010. "Occupational status and the experience of anger." *Social Forces* 88: 2079-2104.

d. Synergistic activities.

1. Editorial Work: I am currently serving on the editorial board of five social science journals: *American Sociological Review, Sociological Forum, Social Forces, Theory and Society, Social Currents, Journal for the Theory of Social Behaviour, Poetics* and *The Journal for World Systems Research*. I am also a member of the International Scientific Board for *Sociologica: Italian Online*

Sociological Review. In addition, I was co-editor of *Perspectives: The Newsletter for the Theory Section of the American Sociological Association* from 2005-2011.

2. Professional Service: I am currently an elected council member of the Sections for the Sociology of Culture and Theory of the American Sociological Association. In addition, I have organized several panels at national conferences during the past two years, including a special session on "Cognitive Science and methodological practice in sociology: Implications, challenges and prospects" at the 2011 American Sociological Association meetings in Las Vegas, Nevada. I have also been an invited speaker at several national and international workshops during the past three years, including a recent Symposium on Social Science and Sustainable Consumption, at the University of Helsinki.
3. Awards: I have received multiple funding and recognition awards from NSF and the American Sociological Association.
4. Interdisciplinary Service: I am a faculty fellow at the Kroc Institute for Peace Studies and the Nanovic Institute for European studies at the University of Notre Dame. In addition I am a current member of the Interdisciplinary Center for Network Science and Applications (ICenSA) at the University of Notre Dame.

e. Collaborators & other affiliations.

1. **Collaborators**.

Nitesh V. Chawla	University of Notre Dame
Jessica Collet	University of Notre Dame
David Hachen	University of Notre Dame
Shu Liu	University of Notre Dame
Lei Meng	University of Notre Dame
Christian Poellabauer	University of Notre Dame
Troy Raeder	University of Notre Dame
Sara Skiles	University of Notre Dame
Aaron Striegel	University of Notre Dame
Zoltán Toroczkai	University of Notre Dame

2. **Graduate advisor**.

Ronald L. Breiger	University of Arizona

3. **Thesis advising.**

Christopher Haussman (Ph.D), Justin Farrell (Ph.D) Melissa Pirkey, Ana Velitchkova, Sara Skiles, Michael Penta, Brandon Sepulvado.

David W. Nickerson

Training

Yale University: Ph.D., Political Science, 1998-2005.
Williams College: B.A., Mathematics and Philosophy, 1993-1997.

Appointments

University of Notre Dame, Associate Professor, Political Science, 2011 – Present.
University of Notre Dame, Assistant Professor, Political Science, 2005 – 2011.
Visiting Fellow, Center for the Study of Democratic Politics, Princeton University, 2009-2010.
Visiting Research Associate, Institution for Social and Policy Studies, Yale University, 2007-2008.
University of Notre Dame, Visiting Research Fellow, 2004-2005.

Products

Nickerson, David W. 2008. "Is Voting Contagious? Evidence from Two Field Experiments," *American Political Science Review* 102(February):49-57.

Nickerson, David W. 2011. "Social Networks and Political Context." in *Handbook of Experimental Political Science*, edited by Jamie Druckman, Donald P. Green, James Kuklinski, and Skip Lupia. Cambridge University Press, p. 273-288.

Fowler, James H., Michael T. Heaney, David W. Nickerson, John F. Padgett, and Betsy Sinclair. 2011. "Observing Causal Effects in Political Networks." *American Politics Research* 39(2):437-480.

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Synergistic Activities

"Social Influence Field Experiments in Networks: Models and Considerations" NSF sponsored workshop at the 6th Annual Political Networks Workshops and Conference, University of Indiana, Bloomington, IN, June 27, 2013.
Director of Experiments, Obama for America, September 2011 – November 2012.
Senior Research Advisor, Analyst Institute, 2007 – Present.

Collaborators

Kevin Arceneaux, Temple University
Elizabeth Bennion, Indiana Univesity South Bend
Ezequiel Gonzalez-Ocantos, CIDE (Mexico City)
Michael Hanmer, University of Maryland
Douglas Hess, Grinnell College
Christopher Mann, Louisiana State University

Graduate Advisors

Alan Gerber, Yale University
Donald Green, Columbia University

Thesis Advisor

Michael Keane, June 2010 (committee member): Operations Research, Loyola Marymount

Lauren Deschamps, June 2013 (chair): Senior analyst, Analyst Institute

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(a) Professional Preparation

- Diploma de Licensâ, Theoretical Physics, Babes-Bolyai University, Romania, June 1992
- Ph.D. Theoretical Physics, Virginia Tech, May 1997
- Postdoctoral Associate, Virginia Tech, 1997-1998.
- Postdoctoral Associate, University of Maryland at College Park, 1998-2000.
- Director's Fellow (postdoc), Los Alamos National Lab (LANL), 2000-02

(b) Appointments

- 2011- Professor, Department of Physics University of Notre Dame, 2011-
- 2011- Concurrent Professor, Computer Science and Engineering, Univ. Notre Dame
- 2007-11 Director, Interdisciplinary Center for Network Science and Applications, Univ. of Notre Dame.
- 2004-06 Deputy Director, Center for Nonlinear Studies, Los Alamos Natl. Lab (LANL),
- 2002-06 Technical Research Staff Member, T-13 (Complex Systems Group) LANL

(c) Products

i. 5 Products Related to the Project

- C. Wang, O. Lizardo, D. Hachen, A. Strathman, Z. Toroczkai, and N. V. Chawla. A dyadic reciprocity index for repeated interaction networks. Network Science, 1(01), 31-48 (2013).
- M. Ercsey-Ravasz and Z. Toroczkai. Centrality scaling in large networks. Physical Review Letters 105, 038701 (2010).
- S. Sreenivasan, R. Cohen, E. Lopez, Z. Toroczkai, H.E. Stanley. Structural bottlenecks for communication in networks. Physical Review E. 75, 036105 (2007).
- S.Eubank, H.Guclu, V.S.A.Kumar, M.V.Marathe, A.Srinivasan, Z.Toroczkai, and N.Wang, "Modelling Disease Outbreaks in Realistic Urban Social Networks", Nature, 429, 180 (2004).
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ii. Other Significant Products

- N.T. Markov, M. Ercsey-Ravasz, D.C. Van Essen, K. Knoblauch, Z. Toroczkai, H. Kennedy. Cortical high-density counter-stream architectures. Science, 342(6158), 1238406 (2013).
- M. Ercsey-Ravasz and Z. Toroczkai. Optimization hardness as transient chaos in an analog approach to constraint satisfaction. Nature Physics 7, 966-970 (2011).
- M. Anghel, Z. Toroczkai, K.E. Bassler, and G. Korniss, "Competition-Driven Network Dynamics: Emergence of a Scale-Free Leadership Structure and Collective Efficiency", Physical Review Letters 92, 058701 (2004).

- G. Korniss, M.A. Novotny, H. Guclu, Z. Toroczkai and P.A. Rikvold, "Suppressing Roughness of Virtual Times in Parallel Discrete-event Simulations", Science, 299, 677 (2003).
- G. Korniss, Z.Toroczkai, M.A. Novotny, and P.A. Rikvold, "From Massively Parallel Algorithms and Fluctuating Time Horizons to Non-equilibrium Surface Growth", Physical Review Letters 84, 1351 (2000).

(e) Synergistic activities:

- Director of the Interdisciplinary Center for Network Science and Applications, Univ. of Notre Dame, 2007-11.
- Deputy Director of the CNLS, LANL, overseeing a postdoc program of 24 postdocs/yr, a GRA summer research program of 15 students/yr, a visitor program of about 200 visitors/yr, and a workshop program with 8-10 workshops per year.
- Organizer or co-organizer of 20 conferences or workshops
- Guest editor, CHAOS, special focus issue on Optimization in Complex Networks,2007;
- Editor, Lecture Notes in Physics Series, Complex Networks, Eds. E. Ben-Naim, Z. Toroczkai and H. Frauenfelder, Springer-Verlag, 2004

(f) Collaborators and other Affiliations

i. Collaborators and Co-Editors (past 48 months)

G. Korniss, Rensselaer Polytechnic Institute; *K.E. Bassler*, Univ of Houston; *M. Ercsey-Ravasz*, Babes-Bolyai Univ., Romania; *H. Kennedy*, INSERM 846, Lyon, France; *I. Miklos* and *P.L. Erdos*, Renyi Inst of Mathematics, Budapest, Hungary; *L. Szekely*, Univ South Carolina; *C.I. Del Genio*, Univ of Warwick, UK; *J. Baranyi*, Inst of Food Research, UK.

ii. Graduate Advisors and Postdoctoral Sponsors

Royce K.P. Zia, Virginia Tech, Ph.D. advisor
Sankar Das Sarma, University of Maryland, postdoctoral advisor.

iii. Thesis adviser and Postgraduate-Scholar sponsor

Thesis advisor (PhD) at Notre Dame for (5 students): Yihui Ren (ND), Melinda Varga (ND), Andrea Asztalos (NIH), Hyunju Kim (Virginia Tech), Anthony Strathman. Thesis co-advisor at ND for Tanya Salyers (IMDB), Pu Wang (Central South Univ China).
Total number of postdocs advised at ND (3 postdocs): Sameet Sreenivasan (RPI), Maria Ercsey-Ravasz (Babes-Bolyai U), Szabolcs Horvat (ND).
Total number of PhD students mentored at LANL (2002-06): 5 students
Total number of Postdocs advised at LANL (2002-06): 6 postdocs

Biographical Sketch

Lijuan (Peggy) Wang, Ph.D.

Department of Psychology, Haggar Hall 111, University of Notre Dame, Notre Dame, 46556

Position Title: Assistant Professor

Professional Preparation:

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	YEAR	FIELD OF STUDY
Renmin University of China, Beijing, China	B.S.	2000	Statistics
Renmin University of China, Beijing, China	M.S.	2003	Statistics
University of Virginia, Charlottesville, VA, USA	M.A.	2005	Quantitative Psychology
University of Virginia, Charlottesville, VA, USA	Ph.D.	2008	Quantitative Psychology

Professional Appointments:

2008- Assistant Professor, Department of Psychology, University of Notre Dame

Products:

Five products related to this proposal

1. Zhang, Q.* & **Wang, L.** (In press). Aggregating and testing intra-individual correlations: methods and comparisons. *Multivariate Behavioral Research*.
2. **Wang, L.** & Preacher, K. J. (In press). Moderated mediation analysis using Bayesian methods. *Structural Equation Modeling*.
3. **Wang, L.**, Hamaker, E., & Bergeman, C. (2012). Investigating inter-individual differences in short-term intra-individual variability. *Psychological methods,* 17(4), 567-581.
4. Zhang, Z., & **Wang, L.** (2012). Methods for mediation analysis with missing data. *Psychometrika,* 78(1), 154 -184.
5. **Wang, L.**, & McArdle, J. J. (2008). A simulation study comparison of Bayesian estimation with conventional methods for estimating unknown change points. *Structural Equation Modeling*, 15, 52-74.

Five other products

1. **Wang, L.** & Grimm, K. J. (2012). Investigating reliabilities of intraindividual variability indicators. *Multivariate Behavior Research*, 47 (5), 1-31.
2. **Wang, L.** & Zhang, Z. (2011). Estimating and testing mediation effects with censored data. *Structural Equation Modeling,18*,18-34.
3. **Wang, L.** (2010). IRT-ZIP modeling for multivariate zero-inflated count data. *Journal of Educational and Behavioral Statistics,35,* 671-692.
4. Zhang, Z. & **Wang, L.** (2009). Statistical power analysis for longitudinal data using SAS. *Behavioral Research Methods*, 41(4), 1083-1094.
5. **Wang, L.,** Zhang, Z., McArdle, J. J., & Salthouse, T. A. (2008). Investigating ceiling effects in longitudinal data analysis. *Multivariate Behavioral Research*, *43(3)*, 476-496.

Synergistic Activities:

Active reviewers for journals such as Psychological Methods, Psychometrika, Multivariate Behavioral Research, Behavioral Research Methods, Methodology, and Journal of Educational Psychology. Reviewers for NSF.

Collaborations and other Affiliations:

Collaborators
Cindy Bergeman, University of Notre Dame
Dawn Gondoli, University of Notre Dame
Kevin Grimm, University of California at Davis
Ellen Hamaker, Utrecht University
Anita Kelly, University of Notre Dame
Irene Park, Indiana University School of Medicine - South Bend
Kristopher Preacher, Vanderbilt University
Scott Maxwell, University of Notre Dame
Timothy Salthouse, University of Virginia
Zhiyong Zhang, University of Notre Dame

Graduate advisors:
John R. Nesselroade, University of Virginia
John J. McArdle, University of Southern California

Number of graduate students advised within the last 5 years: 3
Qian Zhang
Han Du
Charlotte Cunningham

Dr. Aaron D. Striegel

Associate Professor, Associate Chair
Department of Computer Science and Engineering
University of Notre Dame
Notre Dame, IN 46556-0309

Phone: (574) 631-6896
Fax: (574) 631-9260
http://www.cse.nd.edu/~striegel
striegel@nd.edu

Education:

1998	B.S. – Computer Engineering	Iowa State University
2002	Ph.D. - Computer Engineering	Iowa State University

Professional Experience:

2009 – Present	Associate Professor, Department of Computer Science and Engineering, University of Notre Dame (2012+, Associate Chair)
2003 – 2009	Assistant Professor, Department of Computer Science and Engineering, University of Notre Dame
1998 – 2002	Graduate Research Assistant, Iowa State University

Honors and Awards:

2012	Selected Participant - National Academy / Keck Futures Initiative Informed Brain in a Digital World
2012	Selected Participant - National Academy Frontiers of Engineering Education
2009	2nd Place Team Adviser – Enterprise Network Activities Visualizer – National Security Innovation Competition
2003	NSF CAREER Award
2002	ISU Research Excellence Award
2000	NSF Graduate Research Fellowship – Honorable Mention

3 Best Paper Awards: ACM HotPlanet (2013), IEEE Healthcom (2011), USENIX LISA (2008)

Professional affiliations

Institute of Electrical and Electronics Engineers (IEEE), IEEE Computer Society, IEEE Communications Society, Association for Computing Machinery (ACM).

Synergistic activities

- 8 publications – Frontiers in Education
- Creation of the WiiLAB educational tool bridging MATLAB and the Nintendo Wiimote for course instruction
- NSF REU Site co-PI

Five products most relevant to this proposal

1. A. Striegel, **S. Liu, L. Meng**, C. Poellabauer, D. Hachen, O. Lizardo, "Lessons Learned from the NetSense Smartphone Study," in *Proc. of ACM HotPlanet (workshop at ACM SIGCOMM),* Hong Kong, Aug 2013. **Best Paper Award**
2. **S. Liu**, A. Striegel, "Exploring the Potential in Practice for Opportunistic Networks Amongst Smart Mobile Devices," in *Proc. of ACM MOBICOM*, pp. 315-326, Miami, FL, Sep 2013.
3. S. Liu, A. Striegel, "Casting Doubts on the Viability of WiFi Offloading," in *Proc. of CellNet*, Helsinki, Finland, August 2012.
4. **D. Van Bruggen, S. Liu**, M. Kazjer, A. Striegel, C. Crowell, J. D'Arcy, "Modifying User Smartphone Locking Behavior," in *Proc. of SOUPS (Symposium on Usable Privacy and Security)*, Newcastle, UK, July 2013.
5. L. Shi, **Q. Liao**, Y. He, R. Li, A. Striegel, Z. Su, “SAVE: Sensor Anomaly Visualization Engine,” in *Proc. of IEEE VAST 2011*, Providence, RI, October 2011.

Five other products

6. **Q. Liao**, A. Striegel, "Intelligent Network Management Using Graph Differential Anomaly Visualization," in *Proc. of IEEE/IFIP Network Operations and Management Symposium (NOMS 2012)*, Maui, HI, 2012.
7. **Q. Liao**, A. Striegel, N. Chawla "Visualizing Graph Dynamics and Similarity for Enterprise Network Security and Management," in *Proceeding of the ACM 7th International Symposium on Visualization for Cyber Security (VizSec'10)*, Sept. 2010.
8. **Q. Liao, A. Blaich**, A. Striegel, D. Thain, "ENAVis: Enterprise Network Activities Visualization," in *Proc. of LISA (Large Installation System Administration) Conference*, San Diego, CA, Nov. 2008 **Best Paper Award**.
9. **S. Liu**, **Y. Jiang**, A. Striegel, "Accurate Extraction of Face-to-Face Proximity Using Smartphones and Bluetooth," to appear in *IEEE Transactions on Mobile Computing*.
10. **Q. Liao, A. Blaich, D. VanBruggen**, A. Striegel, "Managing Networks through Context: Graph Visualization and Exploration," *Computer Networks*, vol. 54, no. 16, pp. 2809-2824, Nov. 2010.

Graduate students and post-graduate advisees:

Total graduate students advised: 18 Total number of post-docs supervised: 0

Dave Salyers, Chad Mano, Xiaolong Li, Yingxin Jiang, Justin Wozniak, Dave Cieslak, Qi Liao, Mike Chapple, Tim Wright, Andrew Blaich, David Moore, Jerome Krusczek, Dirk VanBruggen, Shu Liu, Michael Olsen, Lei Meng, Rachael Purta, Xueheng Hu

Advisors:

Ph. D.: G. Manimaran (Assistant Professor, Electrical & Computer Engineering, Iowa State University)

Collaborators (with whom have written paper or proposal in the last 48 months):

Notre Dame collaborators are not listed by virtue of natural conflict of interest

Geoffrey Challen (SUNY Buffalo); Ed Chi (Google); Doug Eck (Google); Hamed Haddadi (Queen Mary - Univ. of London); Pan Hui (HKUST); Li Erran Li (Alcatel-Lucent); Jeffrey Liew (Texas A&M); William McDonald (Alcatel-Lucent); Archan Misra (Univ. Singapore); Bruce Mueller (Motorola Solutions)

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
University of Notre Dame

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
David Hachen

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. **David Hachen - PD/PI**	0.00	0.00	1.00	**8,503**	
2. **Omar Lizardo - Co-PD/PI**	0.00	0.00	0.50	**6,116**	
3. **David Nickerson - Co-PD/PI**	0.00	0.00	0.50	**6,644**	
4. **Aaron Striegel - Co-PD/PI**	0.00	0.00	0.25	**3,459**	
5. **Zoltan Toroczkai - Co-PD/PI**	0.00	0.00	0.50	**6,973**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.50	**4,458**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	3.25	**36,153**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**100,000**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**4**) GRADUATE STUDENTS				**75,848**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**212,001**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**38,035**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**250,036**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**8,000**	
2. FOREIGN				**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				**1,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**7,600**	
TOTAL OTHER DIRECT COSTS				**8,600**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**266,636**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC_On_campus (Rate: 52.0000, Base: 266636)**					
TOTAL INDIRECT COSTS (F&A)				**138,651**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**405,287**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**405,287**	

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

PI/PD NAME
David Hachen

ORG. REP. NAME*
Liz Rulli

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Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
Wang, Lijuan - Co-PD/PI	0.00	0.00	0.50	4458

SUMMARY PROPOSAL BUDGET

YEAR 2

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Notre Dame

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
David Hachen

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. **David Hachen - PD/PI**	0.00	0.00	1.00	**8,758**	
2. **Omar Lizardo - Co-PD/PI**	0.00	0.00	0.50	**6,301**	
3. **David Nickerson - Co-PD/PI**	0.00	0.00	0.50	**6,843**	
4. **Aaron Striegel - Co-PD/PI**	0.00	0.00	0.25	**3,563**	
5. **Zoltan Toroczkai - Co-PD/PI**	0.00	0.00	0.50	**7,182**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.50	**4,591**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	3.25	**37,238**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**103,000**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**4**) GRADUATE STUDENTS				**78,123**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**218,361**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**39,176**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**257,537**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**10,000**	
2. FOREIGN				**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				**1,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**1,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**268,537**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC_On_campus (Rate: 52.0000, Base: 268537)**					
TOTAL INDIRECT COSTS (F&A)				**139,639**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**408,176**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**408,176**	

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

PI/PD NAME
David Hachen

ORG. REP. NAME*
Liz Rulli

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Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 2

Other Senior Personnel Name - Title	Cal	Acad	Sumr	Funds Requested
Wang, Lijuan - Co-PD/PI	0.00	0.00	0.50	4591

SUMMARY PROPOSAL BUDGET

YEAR 3

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Notre Dame

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
David Hachen

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. **David Hachen - PD/PI**	0.00	0.00	1.00	**9,021**	
2. **Omar Lizardo - Co-PD/PI**	0.00	0.00	0.50	**6,490**	
3. **David Nickerson - Co-PD/PI**	0.00	0.00	0.50	**7,048**	
4. **Lijuan Wang - Co-PD/PI**	0.00	0.00	0.50	**4,729**	
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**4**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.50	**27,288**	
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. (**3**) GRADUATE STUDENTS				**58,721**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**86,009**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**11,221**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**97,230**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**12,000**	
2. FOREIGN				**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				**1,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**10,000**	
TOTAL OTHER DIRECT COSTS				**11,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**120,230**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC_On_campus (Rate: 52.0000, Base: 120230)**					
TOTAL INDIRECT COSTS (F&A)				**62,520**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**182,750**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**182,750**	

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

PI/PD NAME
David Hachen

ORG. REP. NAME*
Liz Rulli

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Notre Dame

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
David Hachen

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. **David Hachen - PD/PI**	0.00	0.00	3.00	**26,282**	
2. **Omar Lizardo - Co-PD/PI**	0.00	0.00	1.50	**18,907**	
3. **David Nickerson - Co-PD/PI**	0.00	0.00	1.50	**20,535**	
4. **Aaron Striegel - Co-PD/PI**	0.00	0.00	0.50	**7,022**	
5. **Zoltan Toroczkai - Co-PD/PI**	0.00	0.00	1.00	**14,155**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	1.50	**13,778**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	9.00	**100,679**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**4**) POST DOCTORAL SCHOLARS	24.00	0.00	0.00	**203,000**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**11**) GRADUATE STUDENTS				**212,692**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**516,371**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**88,432**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**604,803**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**30,000**	
2. FOREIGN				**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				**3,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**17,600**	
TOTAL OTHER DIRECT COSTS				**20,600**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**655,403**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**340,810**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**996,213**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**996,213**	

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

PI/PD NAME
David Hachen

ORG. REP. NAME*
Liz Rulli

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Date Checked	Date Of Rate Sheet	Initials - ORG

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

Salaries and Wages

Salaries and wages (including stipends) are based on the 2013-2014 University of Notre Dame budget with 3 percent annual increments.

Benefits

Employee benefits are direct charged as a percentage of salaries and wages as follows:

Regular Faculty-Full Time	26.7%
Post-Doctoral Staff	23.3%
Graduate Students	6.7%

Timeframe

The budget is slated to cover three years. Years 1 and 2 will focus on data analysis and modeling. Year 3 will focus on dissemination.

Personnel

The grant will be managed by PI Hachen who will coordinate the effort of an interdisciplinary team consisting of 4 other co-PIs and one Faculty Affiliate.

- ***PI Hachen***: 1 summer month per year is requested for the PI to manage all aspects of the project including data analysis, modeling, dissemination, and the planned conference. Hachen will supervise the social science post-doc and with Lizardo one of the graduate student assistants. Hachen will be the contact person for all IRB related issues. Hachen's expertise in social network analysis and network science and his extensive experience working on large inter-disciplinary projects makes him well suited to guide this project.
- ***Co-PI Lizardo***: ½ a summer month in each year is requested for Lizardo. Lizardo will supervise with Hachen one graduate student and will work with the social science post-doc. Lizardo, an expert in social networks, culture and social theory, will be heavily involved in clarifying and specifying theoretical models, and will work with Toroczkai in developing the agent based models. Lizardo will also supervise work on changing cultural tastes and traits, and will help Hachen organize the conference.
- ***Co-PI Toroczkai***: ½ a summer month in each of the first two years is requested for Toroczkai. Toroczkai will be responsible for the agent based modeling and will help the team in the development of our dynamic models. He will supervise the physics post-doc.
- ***Co-PI Nickerson***: ½ a summer month in each year is requested for Nickerson. Nickerson, an expert on voting and related political behaviors, will be primarily responsible the analysis of how social network ties impact political and social attitudes and voting preferences. Nickerson will also work with Wang on the development of the longitudinal statistical models. He will supervise one graduate student throughout the three years of the project and will work with the social science post-doc.
- ***Co-PI Wang***: ½ a summer month in each year is requested for Wang. Wang, an expert on longitudinal data analysis and multi-level models will play a critical role in model formulation and analyses of behavioral changes. Wang will work with Nickerson on mapping out changes in attitudes and behaviors with a specific focus on mental health. She will supervise one graduate student throughout the three years of the project, and will work with the social science post-doc.
- ***Faculty Association Striegel***: 1/4 of a summer month in the first two years of the project. Striegel, an expert on wireless networks, network security and network visualization will be primarily responsible for data management and assuring data security. He will also play a major role in network visualization and will work with the physics post-doc on computational and visualization issues.
- ***Post-Doctoral Fellow (Social Science):*** 12 months of support in years one and two for

a qualified post-doctoral fellow in one of the social science disciplines (sociology, psychology, political science) who has expertise in social networks and network modeling. This person will be supervised by Hachen and one of the other social science members of the team, with the person depending on the discipline of the post-doc. The post-doc will work with the social science senior personnel in mapping trends and network evolution, formulating and assessing models, facilitating data analysis, making presentations at conferences and co-authoring papers on network evolution and behavioral change.

- ***Post-Doctoral Fellow (Physics)*****:** 12 months of support in years one and two for a qualified post-doctoral fellow in Physics with an expertise in dynamical systems and modeling complex systems. The physics post-doc will be supervised by Toroczkai and will work extensively with him on the agent-based models and our dynamic models of network-behavior coupling.
- ***Graduate Students*****:** Funds are requested for three social science graduate students, one each in sociology, psychology and political science for 9 months of support in each of the 3 years of the project. The sociology graduate student will be supervised by Hachen and Lizardo, the political science student by Nickerson and the psychology student by Wang. Funds are requested for one graduate student in computer science and engineering for 9 months in years one and two. This student will be supervised by Striegel and conduct research on network visualization and algorithmic modeling.

Travel

$8,000 is budgeted for travel in year one, $10,000 in year two and $12,000 in year three for travel by senior personnel and post-docs to conferences to present papers and conduct workshops. Each year Hachen and Lizardo will attend the International Network for Social Network Analysis (INSNA) Sunbelt Conference. In year three, Toroczkai and Hachen will attend the annual NetSci conference which brings together network research from the sciences, medical sciences, engineering, and the social and behavioral sciences. Nickerson will attend in years two and three the PolNet conference sponsored by the political networks section of the American Political Science Association. Wang, will attend in years two and three the Association for Psychological Science annual conference. We have also budgeted 2 conferences for the postdocs in year 1 and 1 in year 2. Because the locations of the conferences change from year to year, we are budgeting based on an estimated average cost of $2,000 for each conference (fees, travel, hotel, per diem).

Other Direct Costs

Supplies

- $1,000 in each year for miscellaneous supplies
- $3,000 in Year 1 for statistical software licenses (STATA, HLM)
- $4,600 in Year 1 for 3 computers @$1,200 each for the two post-docs and the project manager

Conference

$7,000 is budgeted for a conference tentatively entitled “Social Networks as Dynamic Systems” to be held in Spring 2017 during the third year of the project. The total estimated cost of the conference is $30,000. Additional funds for the conference will come from internal sources such as a Henkels grant through the Institute for Scholarship in Liberal Arts (up to $20,000) and contributions from social science departments, iCeNSA, and the Center for Research Computing

Summer Institute

$3,000 is budgeted for a one week summer research institute on modeling social networks as dynamic systems to be held through the Interdisciplinary Center for Network Science and Applications at the University of Notre Dame in the Summer of 2017 (year 3 of the project). Additional funds for this summer research institute will come from internal sources including iCeNSA funds.

Current and Pending Support

(See GPG Section II.D.8 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: **David Hachen**	Other agencies (including NSF) to which this proposal has been submitted:

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

Project/Proposal Title: **SoCS: Explorations on the Effects of Pervasive Networking on Social Relationships and Resource Planning**

Source of Support: **National Science Foundation**

Total Award Amount: $ **764,825** Total Award Period Covered: **08/01/2010 – 07/31/2013**

Location of Project: **University of Notre Dame**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **1.00**

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

Project/Proposal Title: **MRI: Acquisition of Data Analysis Cluster for Computational Social Science**

Source of Support: **National Science Foundation**

Total Award Amount**: $451,839** Total Award Period Covered: **8/01/2012-7/31/2015**

Location of Project: **University of Notre Dame**

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

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

Project/Proposal Title: **NeTS: SoCS: Large: LiveCell: A Comprehensive Approach at Addressing the Small Cell Complexity Tsunami (this proposal)**

Source of Support: **National Science Foundation**

Total Award Amount: **: $ 2,990,500** Total Award Period Covered: **08/01/2013 – 07/31/2017**

Location of Project: **University of Notre Dame**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr**: 1.00**

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

Project/Proposal Title: **IBSS: Social Networks as Coupled Dynamic Systems**

Source of Support **National Science Foundation**

Total Award Amount: **$996,213** Total Award Period Covered: **09/01/2014 – 08/31/2017**

Location of Project: : **University of Notre Dame**

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: **1.00**

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*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 GPG Section II.D.8 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: David Hachen, Ph.D.

Other agencies (including NSF) to which this proposal has been/will be submit-

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

Project/Proposal Title:

Using Smart Devices to Capture the Emotionality of Offline Communication

Source of Support: National Academies Keck Futures Initiative

Total Award Amount: $100,000 Total Award Period Covered: 7/1/13-6/30/14

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. 0 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

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

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:

*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 GPG Section II.D.8 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: Omar Lizardo, Ph.D.

Other agencies (including NSF) to which this proposal has been/will be submit-

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

Project/Proposal Title:

Using Smart Devices to Capture the Emotionality of Offline Communication

Source of Support: National Academies Keck Futures Initiative

Total Award Amount: $100,000 Total Award Period Covered: 7/1/13-6/30/14

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. 0 Cal: Acad: Sumr:

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

Project/Proposal Title:

Doctoral Dissertation Research: Peer Influence and Aesthetic Taste

Source of Support: National Science Foundation

Total Award Amount: $9,100 Total Award Period Covered: 4/1/12-3/31/14

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. 0 Cal: Acad: Sumr:

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

Project/Proposal Title:

SoCS: Explorations on the Effects of Pervasive Networking on Social Relationships and Resource Planning

Source of Support: National Science Foundation

Total Award Amount: $13,500 Total Award Period Covered: 5/23/13-7/31/14

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. 0 Cal: Acad: Sumr:

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

Project/Proposal Title:

IBSS: Social Networks as Coupled Dynamic Systems

Source of Support: National Science Foundation

Total Award Amount: $996,213 Total Award Period Covered: 9/1/14-8/31/17

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.5

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:

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*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 GPG Section II.D.8 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: David Nickerson, Ph.D.

Other agencies (including NSF) to which this proposal has been/will be submit-

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

Project/Proposal Title:

IBSS: Social Networks as Coupled Dynamic Systems

Source of Support: National Science Foundation

Total Award Amount: $996,213 Total Award Period Covered: 9/1/14-8/31/17

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.5

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

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:

*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 GPG Section II.D.8 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: Zoltan Toroczkai (PI)	Other agencies (including NSF) to which this proposal has been/will be submitted: DARPA

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

Project/Proposal Title:

Ensemble-Based Modeling of Large Graphs and its Applications to Social Networks.

Source of Support: DARPA / AFOSR

Total Award Amount: $ 2,344,893 Total Award Period Covered: 48months

Location of Project: University of Notre Dame and 3 subcontractors (U. South Carolina, RPI, U. Houston)

Person-Months Per Year Committed to the Project. 1.5 Cal: 1.5 Acad: 0.5 Sumr: 1

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

Project/Proposal Title:

Understanding the Fundamental Principles Underlying the Survival and Efficient Recovery of Robust Multiscale Techno-social Networks following a WMD Event (2yr extension).

Source of Support: Defense Threat Reduction Agency (DTRA)

Total Award Amount: $500,000 Total Award Period Covered: 24months

Location of Project: University of Notre Dame. Subcontractor: Northeastern

Person-Months Per Year Committed to the Project. 1.5 Cal: 1.5 Acad: 0.5 Sumr: 1

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

Project/Proposal Title:

IBSS: Social Networks as Coupled Dynamic Systems

Source of Support: National Science Foundation

Total Award Amount: $996,213 Total Award Period Covered: 9/1/14-8/31/17

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.5

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:

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*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 GPG Section II.D.8 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: Lijuan Wang

Other agencies (including NSF) to which this proposal has been/will be submit-

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

Project/Proposal Title:

The Science of Honesty

Source of Support: John Templeton Foundation

Total Award Amount: $349,999 Total Award Period Covered: 2011-2014

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. Cal: Acad: 1.2 Sumr:

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

Project/Proposal Title:

Discrimination and Mental Health in Latino Families: Mediators and Moderators.

Source of Support: National Institute of Mental Health

Total Award Amount: $44,807 Total Award Period Covered: 2013-2015

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. Cal: Acad: 0.75 Sumr:

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

Project/Proposal Title:

Brief, Early Preventive Interventions for Months and Fathers in Family Context

Source of Support: National Institute of Health

Total Award Amount: $3,702,371 Total Award Period Covered: 2014-2018

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. Cal: Acad: 1.4 Sumr:

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

Project/Proposal Title:

IBSS: Social Networks as Coupled Dynamic Systems

Source of Support: National Science Foundation

Total Award Amount: $996,213 Total Award Period Covered: 9/1/14-8/31/17

Location of Project: University of Notre Dame

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.5

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:

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*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 GPG Section II.D.8 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: **Aaron D. Striegel** | Other agencies (including NSF) to which this proposal

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

Project/Proposal Title: **REU Site: Experimental Research on Wireless Networking**

Source of Support: **National Science Foundation**
Total Award Amount: $ **354,628** Total Award Period Covered: **01/01/2011 – 12/31/2013**
Location of Project: **University of Notre Dame**
Person-Months Per Year Committed to the Pro- Cal: **0.00** Acad: Sumr: **0.00**

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

Project/Proposal Title: **TC: Small: A Formal Inter-Disciplinary Study of the Impact of Security Awareness on User Behavior**

Source of Support: **National Science Foundation**
Total Award Amount: **$477,783** Total Award Period Covered: **03/01/2010 – 02/27/2013**
Location of Project: **University of Notre Dame**
Person-Months Per Year Committed to the Cal: **0.00** Acad: Sumr: **1.00**

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

Project/Proposal Title: **Curriculum and Laboratory Development Through 3-D Interfacing via Nintendo Wiimote**

Source of Support: **National Science Foundation**
Total Award Amount: **$199,940** Total Award Period Covered: **01/01/2010 – 12/31/2011**
Location of Project: University of Notre Dame
Person-Months Per Year Committed to the Cal: **0.00** Acad: Sumr: **0.75**

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

Project/Proposal Title: **Explorations on the Effects of Pervasive Networking on Social Aware-Behavior Relationships and Resource Planning**

Source of Support: National Science Foundation
Total Award Amount: **$748,825** Total Award Period Covered: **08/01/2010 – 07/31/2013**
Location of Project:
Person-Months Per Year Committed to the Pro- Cal: **0.00** Acad: Sumr: **1.00**

*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 GPG Section II.D.8 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: **Aaron D. Striegel** | Other agencies (including NSF) to which this proposal

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

Project/Proposal Title: **Planning Grant: I/UCRC in Broadband Wireless Technologies Applications**

Source of Support: **National Science Foundation**
Total Award Amount: **$14,554** Total Award Period Covered: **04/01/2013 - 03/31/2014**
Location of Project: **University of Notre Dame**
Person-Months Per Year Committed to the Pro- Cal: **0.00** Acad: Sumr: **0.00**

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

Project/Proposal Title: **IBSS: Social Networks as Coupled Dynamic Systems**

Source of Support: **National Science Foundation**
Total Award Amount: **$996,213** Total Award Period Covered: **09/01/2014 - 08/31/2017**
Location of Project: **University of Notre Dame**
Person-Months Per Year Committed to the Cal: **0.00** Acad: Sumr: **0.25**

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

Project/Proposal Title: **SHB:Small:Use of Gaming Peripherals in Acute Rehabilitation Of Balance Following Stroke**

Source of Support: **National Science Foundation**
Total Award Amount: **$499,999** Total Award Period Covered: **04/01/2011 - 03/31/2014**
Location of Project: **University of Notre Dame / Memorial Hospital (South Bend, IN)**
Person-Months Per Year Committed to the Cal: **0.00** Acad: Sumr: **0.75**

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

Project/Proposal Title:
Using Smart Devices to Capture the Emotionality of Offline Communication

Source of Support: National Academies Keck Futures Initiative
Total Award Amount: $100,000 Total Award Period Covered: 7/1/13-6/30/14
Location of Project: University of Notre Dame
Person-Months Per Year Committed to the Pro- Cal: **0.00** Acad: Sumr: **0.00**

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

Facilities and resources available for this proposed research include:

- *Interdisciplinary Center for Network Science and Applications (iCeNSA):* This university research center facilitates network research across the social science, sciences and engineering. Located on the third floor of Nieuwland Science Hall at the University of Notre Dame it contains 3 faculty offices, one administrative office, 5 student/postdoc rooms with about 22 desk-spaces, a common/library area and a seminar room (occupancy 15). Both postdocs and GAs will be provided with space in iCeNSA. iCeNSA is a highly collaborative place and postdocs and GAs will benefit from the daily contact with faculty and graduate students from a wide variety of disciplines.

- *Center for Research Computing (CRC):* The Notre Dame Center for Research Computing provides a full suite of hosting facilities and computational arrays for researchers at Notre Dame. The facility has a full 10 Gigabit Ethernet connectivity with dedicated 10 Gig E fibers to campus and the commercial Internet / Internet 2. Through a recent NSF MRI grant on which Hachen is a co-PI the CRC has deployed a large memory cluster for computational social science research. The new cluster has over 2,600 CPU cores, 5,300GB of RAM, and 60TB of high performance storage in two racks of data analytics servers connected with a state of the art Infiniband network fabric. This state-of-the-art social science computer cluster will be extensively used for our computational intensive modeling, especially the simulations related to the agent-based models.

Equipment

Not applicable.

I. Types of data

Four types of data will be maintained and used:

- **Research Data**: This data was gathered through the NetSense Project and will be used in this project to analyze changes in social networks, behaviors and attitudes. It consists of two types of data:
    - **Instrumentation data**: Data obtained from smartphones since August 2011 including communication event records (time, date, type of event, sending and receiving phone numbers), location, Bluetooth proximity, application usage, data tonnage, etc. All instrumentation data is initially stored locally on a device and then securely transferred to a secure database housed at the Center for Center for Research Computing (CRC) at the University of Notre Dame. Senior personnel and their graduate students and post-docs will have access to this database, though we will set up a management structure where only a few people at any time can access the data either for themselves or per requests from other team members.
    - **Survey data**: Data obtained from surveys conducted with NetSense participants through the NetSense study will continue to be maintained on secure servers at the Center for Center for Research Computing (CRC) at the University of Notre Dame. Access to this data, which does contain personal information, will be restricted to senior personnel and their graduate students.

  The NetSense Project received ND-IRB approval for the collection, storage and maintenance of this data.

- **Software**: We anticipate developing algorithms and software for models and visualization.
- **Curriculum materials**: As part of the dissemination effort, curriculum materials (exercises, articles, workshop materials, instructional simulations, slides, videos) will be developed. These materials will be stored using the Box system.
- **Evaluation Data**: This includes all documentation, reports, papers, slides and other types of material created as a result of the data analysis and modeling. Maintaining documentation on activities, data extracts and manipulations, results, queries, and problems is essential to the smooth running of a project and our ability to recall what people have done. It will also facilitate dissemination and the writing of papers. A documentation system will be set up through Box to facilitate all of this.

II. Data and Metadata Standards

Software will be stored as source code using versioning systems and also as executables for download from our project website after fully tested. Software will be made available online using standard public licenses (e.g., GPL). Statistical algorithms and routines developed for R or STATA will be distributed through existing systems that are part of these platforms. Reports, documentation and curriculum materials will be stored electronically through Box. Research data will be stored and maintained on highly secure servers in SQL databases.

III. Policies for access and sharing and provisions for appropriate protection/privacy

Software, curriculum materials, and evaluation data (reports, documentation, papers) will be made available online on the project's website so that these data can be accessed using standard web browsers. Logins will be required, but anyone can create an account as long as they provide us with required information (email address, name, affiliation). Working papers will also be archived through arXiv.org. All research data generated through the NetSense project as well as any derivatives from this data will be excluded from public access, except in cases where we have processed such data so that identifying information has been removed through anonymization procedures. All publicly available data will be made available as downloadable databases. There will be no charges for such accesses, but the creator of the data retains the right to use the data before opening it up to wider use if the PI and/or the university believe that this is necessary in order to protect intellectual property for potential commercialization.

IV. Policies and provisions for re-use, re-distribution

Software and data published on our website can be used freely as long as all copyright notices and references to authors are left intact. The data will be of most use to social scientists, network researches, and statisticians. Given our dissemination goals, we expect that both anonymized research data but especially the software we develop for statistical analysis and modeling will be shared and used by others.

V. Plans for archiving and preservation of access

Versioning tools will be used to track the development of software and to store old versions. Evaluation and curriculum will remained stored through Box. Upon becoming available to others, centralized resource networks and repositories will be utilized to facilitate sharing and maintenance of publically available data.

For the research data, its archiving and preservation is being handled through the NetSense project. After the data has been anonymized and cleaned, it will be stored for as long as needed in our repository maintained with secure backups through the CRC at the University of Notre Dame.

Two postdoctoral researchers (postdocs) will be funded on this project, whose development will be enhanced through a program of structured mentoring activities with the goal of providing each postdoc with the skills, knowledge, and experiences needed for career development. We will employ mentoring practices based on the National Academies of Science and Engineering guidelines.[1] The interdisciplinary nature of this project and existence of two postdocs provide unique opportunities for professional development of the postdocs. The Physics postdoc will be directly mentored by Zoltan Toroczkai, the social science postdoc by David Hachen. Specific elements of the mentoring will include:

- **Initial Orientation**: The postdoc will participate in regular events organized by their PI's research groups, including bi-weekly full project and sub-project meetings, individual meetings and seminars. In initial meetings, expectations and responsibilities will be discussed, including working hours, reporting and documentation techniques and tools, equipment and tools purchasing processes, etc. Results will written down for future reference. Hachen and Toroczkai will organize events (student presentations, tutorials, meetings with administrative and technical staff, training through the Center for Research Computing, sharing of grant proposals) so the postdocs are familiar with our research and scientific approaches. The postdocs will also be required to complete "The Collaborative Institutional Training Initiative" online courses so that they are familiar with the ethical issues surrounding human subjects research and the methods used to maintain the confidentiality of data collected from human subjects. Finally, Hachen (and Toroczkai) will establish and implement a customized development plan with their postdoc based on the project's goals, the postdoc's skills and experience, and their expectations.
- **Regular Meetings**. Hachen and Toroczkai will meet regularly with their postdoc to discuss progress on the research including review of design and implementation choices and issues, data management, data analysis and interpretation, model specification and dissemination of results. There will be at least one weekly individual meeting between Hachen (Toroczkai) and his postdoc and the postdoc will also participate in weekly group meetings with the entire research group.
- **Grant Writing**. The postdoc will participate in seminars, workshops, and consultations organized by the PI, the Office of Research, ISLA and other centers at the University of Notre Dame to help identify research funding opportunities and to write competitive proposals.
- **Networking Opportunities**. The postdocs will have an opportunity to network with visiting scholars who are leaders in our disciplinary fields and in network research by participating in various departments' visiting speaker series and via individual meetings with the speakers (e.g., having lunch or dinner with them). The postdocs will also travel to conferences to present a poster or paper.
- **Periodic Assessments**. Hachen and Toroczkai will discuss career goals with the postdoc once per academic semester. Before each meeting, the postdoc will perform a self-assessment to help identify potential career options.
- **Teaching**. The postdocs will be given the opportunity to give occasional lectures in the PIs' courses, followed by a meeting to provide constructive feedback. They will be encouraged to participate in seminars and workshops offered by the Kaneb Center at the University of Notre Dame.
- **Mock Application and Interview**: During each postdoc's second year, a mock application and interview process will occur in which the postdoc prepares teaching and research statements, CV, cover letter, and lists of references. The packet will be reviewed by a mock search committee The postdoc will also give an interview-caliber presentation and meet with faculty in his area (including those not affiliated with the project) for interviews. The candidate will receive from those involved constructive feedback on his/her materials, presentations and interviews.

Success of this mentoring plan will be assessed by tracking the progress of both postdocs through their development plans, interviews with the postdoc fellow to assess satisfaction with the mentoring program, and tracking of each postdoc's progress toward his/her career goals after the grant period.

[1] National Academy of Science, National Academy of Engineering, Institute of Medicine, ``Enhancing the Postdoctoral Experience for Scientists and Engineers: A Guide for Postdoctoral Scholars, Advisers, Institutions, Funding Organizations, and Disciplinary Societies," National Academies Press, 2000

UNIVERSITY OF NOTRE DAME
DEPARTMENT OF SOCIOLOGY

iCeNSA
Interdisciplinary Center for Network Science & Applications

December 1, 2013

s
To: NSF Interdisciplinary Behavioral and Social Science (IBSS) Research Competition
From: David Hachen

By signing or transmitting this message electronically, I acknowledge that I am a PI, co-PI, or other member of the senior personnel for the project outlined in the proposal titled "Modeling Social Networks as Coupled Dynamic Systems" with David Hachen, Ph.D., as the Principal Investigator.

In addition, I confirm that I am not a PI, co-PI, or other member of the senior personnel for any other project submitted to the IBSS competition this fiscal year.

Signed: David S. Hachen Jr.
Organization: University of Notre Dame
Date: 12/1/13

810 Flanner Hall
Notre Dame, Indiana
46556-5611

Telephone (574) 631-5745
Facsimile (574) 631-9238
dhachen@nd.edu

DEPARTMENT OF SOCIOLOGY
University of Notre Dame, Notre Dame, IN 46556

November 18th 2013

To: NSF Interdisciplinary Behavioral and Social Science (IBSS) Research Competition

From: Omar Lizardo

By signing or transmitting this message electronically, I acknowledge that I am a PI, co-PI, or other member of the senior personnel for the project outlined in the proposal titled "Modeling Social Networks as Coupled Dynamic Systems" with David Hachen, Ph.D., as the Principal Investigator.

In addition, I confirm that I am not a PI, co-PI, or other member of the senior personnel for any other project submitted to the IBSS competition this fiscal year.

Signed:

Omar Lizardo
Organization: University of Notre Dame
Date: 11/27/13

UNIVERSITY OF NOTRE DAME
College of Arts and Letters

DEPARTMENT OF PSYCHOLOGY
118 Haggar Hall, Notre Dame, Indiana 46556 USA
tel (574) 631-6650 *fax* (574) 631-8883 *web* psychology.nd.edu

To: NSF Interdisciplinary Behavioral and Social Science (IBSS) Research Competition

From: Lijuan (Peggy) Wang

By signing or transmitting this message electronically, I acknowledge that I am a PI, co-PI, or other member of the senior personnel for the project outlined in the proposal titled "Modeling Social Networks as Coupled Dynamic Systems" with David Hachen, Ph.D., as the Principal Investigator.

In addition, I confirm that I am not a PI, co-PI, or other member of the senior personnel for any other project submitted to the IBSS competition this fiscal year.

Sincerely,

Lijuan Wang

Assistant professor
Department of Psychology
University of Notre Dame
Notre Dame, IN, 46556
Nov 26, 2013

From:	Zoltan Toroczkai
To:	Lori Loftis
Cc:	EXT - dhachen
Subject:	Re: Status Report on Proposal
Date:	Tuesday, November 26, 2013 10:02:32 PM

Dear David,

As requested:

To: NSF Interdisciplinary Behavioral and Social Science (IBSS) Research Competition

From: Zoltan Toroczkai

By signing or transmitting this message electronically, I acknowledge that I am a PI, co-PI, or other member of the senior personnel for the project outlined in the proposal titled "Modeling Social Networks as Coupled Dynamic Systems" with David Hachen, Ph.D., as the Principal Investigator.

In addition, I confirm that I am not a PI, co-PI, or other member of the senior personnel for any other project submitted to the IBSS competition this fiscal year.

Signed: Zoltan Toroczkai
Organization: University of Notre Dame
Date: Nov 26, 2013.

With best wishes,
Zoltan

Zoltán Toroczkai, PhD,
Professor of Physics,
Concurrent Professor of Computer Science and Engineering,
Physics Department, 225 Nieuwland Hall of Science,
University of Notre Dame, Notre Dame, IN, 46556, USA
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Email: toro@nd.edu , Ph: + 574 631-2618
Admin: Ms. Alejandra (Jasmine) Botello (abotello@nd.edu)
Admin Ph: +574 631-7095, Fax: + 574 631-5952
web: http://www.nd.edu/~toro

From: David Nickerson
To: Lori Loftis; EXT - dhachen
Subject: Re: Status Report on Proposal
Date: Saturday, November 30, 2013 11:27:26 AM

To: NSF Interdisciplinary Behavioral and Social Science (IBSS) Research Competition

From: David Nickerson

By signing or transmitting this message electronically, I acknowledge that I am a PI, co-PI, or other member of the senior personnel for the project outlined in the proposal titled "Modeling Social Networks as Coupled Dynamic Systems" with David Hachen, Ph.D., as the Principal Investigator.

In addition, I confirm that I am not a PI, co-PI, or other member of the senior personnel for any other project submitted to the IBSS competition this fiscal year.

Signed: David Nickerson
Organization: University of Notre Dame
Date: November 30, 2013

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November 30, 2013

To: NSF Interdisciplinary Behavioral and Social Science (IBSS) Research Competition

From: Aaron Striegel

By signing or transmitting this message electronically, I acknowledge that I am a PI, co-PI, or other member of the senior personnel for the project outlined in the proposal titled "Modeling Social Networks as Coupled Dynamic Systems" with David Hachen, Ph.D., as the Principal Investigator.

In addition, I confirm that I am not a PI, co-PI, or other member of the senior personnel for any other project submitted to the IBSS competition this fiscal year.

Signed: Aaron Striegel
Organization: University of Notre Dame
Date: November 30, 2013