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Enabling Geographic Research Across Disciplines: Building an Institutional Infrastructure for Geographic Analysis at Harvard University

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1 **Enabling Geographic Research across Disciplines: Building an institutional**
2 **infrastructure for geographic analysis at Harvard University**

3 Weihe Wendy Guan¹, Bonnie Burns², Julia L. Finkelstein³ and Jeffrey C. Blossom⁴

4 **Abstract**

5 Founded in 1818, the Harvard Map Collection (HMC) is the oldest map collection in
6 America, holding 400,000 maps, more than 6,000 atlases and thousands of reference books.
7 HMC has a strong commitment to digital resources and manages the Harvard Geospatial Library,
8 a foundation for geospatial data service at Harvard. The Center for Geographic Analysis at
9 Harvard University (CGA) was founded in 2006, independent of the library system, to serve the
10 entire university. This article presents the history, organizational structure, and operational
11 model of CGA and HMC, reviews achievements, lessons learned, suggests future improvements,
12 and reviews GIS-related medical research at Harvard.

13 **Historical Background**

14 Harvard lost its Geography Department in 1948 (Smith, 1987) and the Computer
15 Graphics and Spatial Analysis Lab in 1991(Chrisman, 2006). The support for maps and

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² Harvard Map Collection

³ Harvard School of Public Health

⁴ Harvard University Center for Geographic Analysis

16 geographic analysis for medicine research and much of the rest of the University fell on the
17 Harvard Map Collection (HMC)⁵ alone, with limited resources. By the early 2000s the
18 University recognized that it was missing out on the potential contributions the new geography -
19 the approach to geospatial analysis that combined Geographic Information Systems (GIS)
20 technology with quantitative analysis - could make to disciplines across the university, from
21 medicine to epidemiology to sociology to history to trade policy. The question the University
22 faced was how most effectively, and quickly, to make it possible for students and faculty to bring
23 geospatial to bear on research and teaching (Guan and Bol, 2010). The Center for Geographic
24 Analysis (CGA)⁶ was established to do just that (Gehrman, 2006), with a mandate to collaborate
25 closely with the Map Collection and the ongoing digital library project named the Harvard
26 Geospatial Library⁷ (HGL; Siegel, et al. 2004).

27 **The History of the Harvard Map Collection**

28 The HMC, a unit under the Harvard College Library, was founded in 1818 with the gift
29 of the Ebeling Collection of 10,000 maps and books, presented to the University by Israel
30 Thorndike (Figure 1). The Collection has grown consistently since that time. With the transfer
31 of maps after the dissolution of Harvard's Institute for Geographic Exploration, the HMC became
32 one of the largest map collections in North America. Visiting the HMC is an opportunity to see
33 some of the cartographic treasures of the world, since the stacks contain not just paper but also
34 digital materials (Figure 2).

⁵ Harvard Map Collection website: <http://hcl.harvard.edu/libraries/maps/>

⁶ Center for Geographic Analysis website: <http://cga.harvard.edu/>

⁷ Harvard Geospatial Library website: <http://hgl.harvard.edu>

35 **Figure 1 New York State by D.F. Sotzmann, 1799. From the Ebeling Collection, Harvard**
36 **Map Collection**

37 **Figure 2 Harvard Map Collection reading room, photograph by Peter Vanderwarker,**
38 **courtesy of Harvard College Library**

39 The HMC began its GIS activities in earnest in 1992. More and more cartographic
40 materials were being made available in digital form, but at that time the HMC had only a single
41 PC and it was dedicated to browsing the library catalog. There were data but no methods for
42 library patrons to access them, since the library had no GIS workstations and the staff had
43 minimal GIS experience. There was no support outside of the library on GIS either. The
44 Harvard Graduate School of Design⁸ had a strong GIS presence, but support was limited to
45 students in that school. For undergraduates and graduate students in other programs, there were
46 very few options.

47 At that time, the Association of Research Libraries (ARL)⁹ launched the GIS Literacy
48 Project, an effort "to introduce, educate, and equip librarians with skills needed to provide access
49 to spatially referenced data in all formats and to provide effective access to selected electronic
50 information resources in library collections"(Adler 1995). ARL solicited donations and support
51 from the GIS industry to achieve its goals of increased GIS presence in academic libraries. The
52 HMC was in the first wave of libraries to be awarded such support and began to build up the

⁸ Harvard GSD website: <http://gsd.harvard.edu>

⁹ ARL website: <http://www.arl.org/>

53 infrastructure and staff needed to provide the research community with a place to go for GIS
54 data, software and help.

55 The first step was to provide access to the materials on the HMC shelves. Computers in
56 the reading room were installed with a variety of GIS and cartographic software programs for
57 general use. Staff were trained in ArcView and started to answer requests from patrons for
58 simple custom map requests. Students and researchers soon saw value of GIS and requests for
59 assistance became more and more complex, to the point where in 1999, a GIS specialist was
60 hired in the HMC to assist with GIS data creation, analysis and programming.

61 In addition to creating an infrastructure for GIS support in the library, the HMC began, in
62 1995, to bring GIS to the Internet via the Massachusetts Electronic Atlas (MEA). Hosted by the
63 HMC and created by Harvard, UMass Boston and the Metropolitan Area Planning Council, the
64 MEA allowed users to map over 200 variables for the state, including extensive health data, as
65 well as crime statistics and natural resources information (Cobb, 1995). The site proved to be
66 quite popular and useful, but did not allow for data downloading and also only covered
67 Massachusetts, and therefore did not include data of interest to most students.

68 A new project was envisioned in 1998, a system that would allow patrons to have access
69 to the rich collection of data in the Harvard libraries at all hours *via* the Internet (Siegel, et al
70 2004). This system would not only serve data for download but include a robust search engine
71 allowing users to quickly find relevant data without having to browse a file system. By 2001, the
72 Harvard Geospatial Library (HGL) was live and receiving 300 hits per day.

73 HGL currently holds over 6,000 data layers that are ready for use in geographic
74 information systems (Figure 3). These layers are at a variety of scales - from global (VMAP 1)
75 to local (cadastral data for Boston) - cover many different areas of the world, and range in age

76 from current to 400 year-old historic maps. The catalog is based on detailed Federal Geographic
 77 Data Committee¹⁰ Content Standard compliant metadata records that allow for finely tuned
 78 searches of the repository. Users can display and download these layers for use in their desktop
 79 software.

80 **Figure 3 The Harvard Geospatial Library Entry Page**

81 In addition to current library holdings, HGL is also a distribution mechanism for
 82 researcher-created datasets. When GIS projects lead to the creation of new data, those files can
 83 be sent to the HMC for inclusion in the repository and catalog. This ability to accept GIS data
 84 for distribution led to further collaborations with the CGA since 2006.

85 **The Establishment of the Center for Geographic Analysis**

86 The field of geographic analysis underwent a series of revolutions in the past half a
 87 century. The quantitative revolution brought quantitative analysis into geography in the 1950s,
 88 which inspired a new generation of students and scholars (Dutton, 2006). The birth of geographic
 89 information systems in the 1960s equipped geographic analysis with computers (Niemann and
 90 Niemann, 1998). Computer cartography and analysis of remotely sensed images in the 1970s
 91 presented new dimensions to the discipline. The integration of geographic analysis with
 92 numerical models gained much ground in the 1980s, especially in the field of environmental
 93 studies. The information technology (IT) boom in the 1990s gave geographic analysis a swift
 94 push into the IT mainstream, complete with relational and object-oriented database management
 95 systems (RDBMS and ODBMS), programming platforms, client server architectures, and web-

¹⁰ FGDC website: <http://www.fgdc.gov>

96 based implementations. The completion of the Global Positioning System (GPS) and the ever
97 increasing earth surveillance satellites resulted in an exponential increase of spatial data in native
98 digital format, feeding content to, and at the same time putting pressure on, the geographic
99 information systems. By the middle of 2000s, Google released Google Maps and Google Earth,
100 which generated a heightened public interest in geographical issues and expanded awareness of
101 geography in other disciplines. The geo-technological revolution is still ongoing as of today,
102 pushing geographic analysis up to computing clouds and down to mobile devices, into the hands
103 of all walks of life. Its continued growth has expanded job market for geographers, increased
104 enrollment in geography departments, and brought improvement in geography education at all
105 levels (Murphy, 2007).

106 In 2003, a faculty committee on spatial analysis was formed at Harvard University, led by
107 Professor Peter Bol, a prominent historian and a pioneer in applying GIS to the study of history.
108 The committee was set to find a solution to address the increasing concerns from faculty and
109 students on improving access to spatial data, support for research employing geospatial analysis,
110 and curriculum development. Two years of investigation and discussion led to the decision by
111 the University President and Provost to establish the Center for Geographic Analysis (CGA). The
112 inauguration of the Center was held in May 5, 2006 (Gehrman, 2006), some called the day “a
113 new dawn for geography at Harvard” (Waters, 2006).

114 From day one, the CGA has been focused on research and education in the field of spatial
115 analysis and geographic information. Building on the foundation established by the HMC and
116 HGL, the CGA was expected to create a more substantial infrastructure to support a wide range
117 of scholarly research projects that wish to apply, improve, or study geospatial analysis

118 techniques. One of the largest and most advanced user groups is Harvard's medical and public
119 health research community.

120 **Multifaceted Medical Research at Harvard University**

121 Medical research is conducted at a number of institutions at Harvard University,
122 including the Harvard School of Public Health, Harvard Medical School (Figure 4), and
123 affiliated hospitals, the Harvard Humanitarian Initiative, the Harvard Initiative for Global Health,
124 and the Faculty of Arts and Sciences. The following section will describe the application of
125 geographic analysis and GIS to medical research being conducted at Harvard University.

126 **Figure 4 The Harvard Medical Campus**

127 **Application of Geographic Analysis to Medical and Public Health Research**

128 The early applications of geographic analysis to medical research can be traced to a small
129 Soho district in London in 1854. John Snow, a British physician, identified the Broad Street
130 water pump as the source for one of the most severe cholera epidemics in history, by using
131 observational data and a series of maps. Based on this work, he is considered the father of
132 modern epidemiology, one of the cornerstones of public health (Singer and de Castro 2001).
133 John Snow's study was a transformative event in the history of medical geography and public
134 health. The handle of the Broad Street pump has become a symbol, marking the integration of
135 medicine, geographic analysis, and public health research.

136 Over 150 years since John Snow's cholera outbreak investigation, geographic analysis
137 remains intricately linked to medical research. The application of spatial analytic techniques to
138 understand the distribution of disease and determinants of health is at the core of medical and
139 public health research. During the past two decades, advances in technologies have made it

140 possible to examine spatial and temporal trends in large-scale epidemiological data with
141 enhanced precision and speed.

142 GIS techniques are ideally suited for public health surveillance and infectious disease
143 control, as transmission of infectious diseases is closely related to geographic proximity. This
144 includes case location, identification of clustering, mapping of epidemic dynamics, and mapping
145 disease burden and response. More recently, geographic analytic methods have been applied to
146 the fields of environmental health and chronic disease epidemiology, to link proximity to
147 exposures to incidence of non-communicable diseases. Application of GIS methods and
148 collaborative data sharing has also contributed to the emerging fields of crisis mapping, response
149 to natural disasters, and infectious disease outbreaks, to inform timely targeted emergency
150 responses, resource allocation, and health care delivery strategies.

151 Understanding spatial and temporal distribution of disease is central to targeting health
152 problems. Using GIS facilitates exploration of a broad range of determinants - such as
153 demographic, socioeconomic, geographic, and environmental factors - from a diverse array of
154 disciplines that influence disease transmission patterns in a single environment.

155 Geographic analysis provides a unique interface between health data and a map - to
156 effectively present information to key decision-makers. GIS methods enable summation and
157 presentation of large amounts of data for disease surveillance and health reporting, and identify
158 new cases, map at-risk populations, stratify risk factors, and quantify distribution of risk and
159 transmission patterns. Optimal summary and visual presentation of complex medical and
160 scientific health data can be used to communicate abstract quantitative data, and inform health
161 care policy, program planning, and health resource allocation. Geographic analysis also informs
162 evidence-based policy and program planning, such as the design, implementation, and

163 monitoring of targeted interventions, and examining patterns of disease burden and health care
164 delivery. Selected examples of applying geographic analysis to medical research at Harvard
165 University are presented in Table 1.

166 **Table 1 Selected Medical Research Projects at Harvard University**

167 **Examples of Geographic Information Systems in Medical Research at Harvard**

168 Geographic analysis and examining medical research questions spatially have helped to
169 integrate medical and public health research across disciplines and departments at Harvard
170 University. For example, the Exposure, Epidemiology and Risk Program (EER) at the Harvard
171 School of Public Health brings together the departments of Environmental Health and
172 Epidemiology to explore environmental and occupational determinants of health and disease, and
173 inform evidence-based policy.

174 Researchers have applied novel GIS techniques and cutting-edge statistical methods to
175 longitudinal epidemiological studies, to answer unanticipated research questions not envisioned
176 at the study onset. The Nurses Health Study, founded in 1976 in the Department of Nutrition, is
177 among the largest and longest running investigations of factors that influence women's health.
178 Started in 1976, this study of over 238,000 nurses has led to many new insights on health and
179 disease. Researchers in the Exposure, Epidemiology and Risk Program, Department of
180 Environmental Health, and the Departments of Nutrition and Epidemiology have applied GIS
181 techniques to analyze data from the Nurses' Health Study, and use semi-empirical models to
182 predict spatially and temporally resolved long-term average outdoor concentrations of particulate
183 matter (PM) (Yanosky, Paciorek et al. 2008) and successfully predict chronic fine and coarse
184 particulate exposures using spatio-temporal models for the Northeastern and Midwestern United

185 States (Yanosky, Paciorek et al. 2009). Spatial methods are also being incorporated into new
186 research designs for longitudinal studies; in fact, the third Nurses Health Study is currently
187 underway over three decades later, to examine environmental and lifestyle exposures of women.

188 Similarly, researchers have applied GIS methods to examine long-term ambient multi-
189 pollutant exposures (PM10, PM2.5, nitrogen dioxide, and sulfur dioxide) in 53,814 men in the
190 US trucking industry, and found that residential ambient air pollution exposures were associated
191 with significantly increased mortality (Hart, Garshick et al. 2010). GIS methods have also been
192 applied to the Harvard Six Cities Study, one of the most influential, innovative and longest-
193 running studies addressing the health effects of air pollution in America; this landmark study has
194 led to the regulation of airborne particulate matter and the development of the Clean Air Act.

195 Geographic analysis has also been used in medical research to target advocacy and social
196 justice in resource-limited settings. In an example of geographic analysis bringing together the
197 university with the community, researchers examined the influence of traffic on air quality in an
198 urban neighborhood (Buonocore, Lee et al. 2009). In this project in the Mission Hill
199 neighborhood of Boston, Massachusetts, GIS methods were used to examine spatial and
200 temporal patterns of traffic-related air pollutants to determine factors contributing to elevated
201 concentrations and inform environmental justice concerns. In another project in Malawi, Africa,
202 investigators used GIS methods and data from the Malawi Health Facility Inventory and the
203 Malawi Demographic and Health Survey to identify disparities in access to modern reproductive
204 health services (Heard, Larsen et al. 2004).

205 Geographic analysis has been transformative in international medical research at Harvard
206 University. GIS technologies have allowed researchers to send portable GPS units to remote field
207 settings to monitor conflict zones, urban slums, and remote villages, and provide precise health

208 data in areas with limited infrastructure. GIS and remote sensing technologies have also been
209 used to identify host habitats and identify clusters of cases, to examine infectious disease
210 transmission patterns, and inform targeted interventions. For example, researchers in the
211 Department of Nutrition at the Harvard School of Public Health used GIS methods to examine
212 ecological determinants of parasitic infections in school children in rural KwaZulu-Natal, South
213 Africa, including *Ascaris lumbricoides* (Saathoff, Olsen et al. 2005) and hookworm (Saathoff,
214 Olsen et al. 2005). Researchers in the department of Global Health and Population also obtained
215 complete coverage of larval control to suppress malaria vector mosquitoes through
216 comprehensive spatial coverage with community-derived sketch maps in Dar es Salaam,
217 Tanzania (Dongus, Nyika et al. 2007). Researchers also used spatial and temporal analysis of
218 malaria risk to inform policies for disease control in the Amazon region in Brazil (Singer and de
219 Castro 2001).

220 Geographic analysis has also emerged with increasingly important humanitarian projects.
221 In the aftermath of natural disasters, such as the 2010 earthquake in Haiti, GIS technologies have
222 played a critical role in rapid and efficient response to crises, and in conducting public health
223 research to develop and monitor evidence-based programs. GIS also plays an important role in
224 crisis mapping initiatives and developing early warning systems to mitigate the effects of natural
225 disasters, avert mass atrocities, strengthen international aid coordination, inform resource
226 allocation, and develop evidence-based humanitarian interventions.

227 The Harvard Humanitarian Initiative (HHI) is a university-wide center involving multiple
228 entities within the Harvard community that provide expertise in public health, medicine, social
229 science, management, and other disciplines to respond to humanitarian complex emergencies. In
230 the Humanitarian Crisis Mapping and Early Warning project, GIS methods and mapping

231 technologies are used to promote evidence-based approaches to humanitarian assistance, and
232 advancing the science and practice of humanitarian response worldwide. For example, in the
233 Incubator Implementation project in Indonesia, GPS devices were used to map remote areas
234 where incubators were placed. Within the HHI and the Harvard medical community at large,
235 researchers understand the utility of GIS technology in their research and use it for a diverse
236 range of projects.

237 **Collaborations Between CGA and HMC**

238 In order to effectively support the diverse needs for geographic analysis from the Harvard
239 medical community as well as the rest of the university at large, CGA established a governing
240 structure which includes faculty members from the medical school and the school of public
241 health in its faculty steering committee, and key GIS professionals from the library and the
242 medical campus in its technical advisory committee. The faculty committee meets once per
243 semester to guide the center in its strategic development, while the technical advisory committee
244 meets three times per semester to advise the center in its technical operation, such as service
245 level and distribution, technology adaptation, outreach event coordination, and feedback from the
246 user community. Staff of HMC and HGL serves on the CGA technical committee, while CGA
247 staff serves on the HGL Standing Committee. This cross-organizational structure provides a
248 forum for regular checks and balance of the shared responsibilities between the CGA and the
249 HMC in optimizing user support.

250 **Data Acquisition, Development, and Sharing**

251 Data is usually the first thing a user asks for when considering geographic analysis.
252 Utilizing each organization's strength, the HMC focuses on systematically acquiring geospatial

253 data, making them available, and helping users find the appropriate data precisely and quickly
254 from the Harvard library holdings. The CGA often refers users to the HMC for data-related
255 questions, such as data availability, source, cost, and format. Patrons interested in historical data
256 are often forced to create that data on their own by digitizing paper maps, and HMC has a larger
257 format scanner that can be used to create an image of any material in the collection. Those
258 images can be georeferenced with assistance from either CGA or HMC and the relevant
259 information can be digitized. When the user receives their data, they may return to CGA for help
260 in analyzing and visualizing the data. If the patron requires less complex analysis or
261 straightforward cartography, they can get that help at HMC.

262 Many research projects require unique data that are not acquired by the library yet and
263 are not available from well known public data sources, such as international data, high resolution
264 images, or custom-created data by a researcher or a research institution. CGA facilitates the
265 identification of such data sources, helps define and clarify the data properties and quality, serves
266 as the liaison between Harvard data users and some data companies and institutions, manages
267 data development service and cross-institutional data sharing contracts, and assists the users in
268 submitting their unique data to the HGL with proper permission. The HMC takes on the
269 responsibility of geospatial data stewardship alone, freeing the CGA to focus on analysis
270 services.

271 Whether data is acquired by CGA or HMC, the goal is to hold onto it and make it
272 available to future researchers. While licensing restrictions sometimes prohibit data sharing,
273 whenever possible, new data are deposited into the HGL. For that the data are delivered to HMC
274 and translated into the HGL accepted format (ArcSDE layers). Metadata that is compliant with
275 the FGDC standard is created by the Harvard College Library geospatial resources cataloger, and

276 the data is published via HGL. Many layers are restricted to Harvard affiliates only, but all
277 metadata is publically searchable so that non-Harvard researchers can at least discover that a data
278 set exists and get information on how to obtain the layer for themselves. Every effort is made to
279 license data for use by the entire Harvard Community. However sometimes that is just not
280 possible, and only a single user is allowed access at any time. In those cases, metadata is still
281 created and placed in the HGL catalog, with information on where to access the data set on
282 campus. By collaborating in this way, CGA and HMC have increased the size and value of the
283 HGL collections as well as the usefulness of the system to patrons.

284 **Software Licenses and Labs**

285 The CGA manages all University-wide geospatial software license contracts, and equips
286 computer labs across the University with updated versions of GIS, image processing, spatial data
287 conversion, visualization and geostatistical analysis software packages from multiple companies,
288 as well as some freeware and open source GIS tools. Most of these software licenses are
289 managed through a centralized license server, with one or two backup servers to maintain
290 uninterrupted availability. The HMC maintains a small lab of PCs equipped with GIS software
291 distributed by CGA, as well as powerful desktop publishing applications that can be used to
292 create professional quality illustrations.

293 The Harvard medical community has unique license requirements because of its
294 geographically distributed nature. Many Harvard Medical School and HSPH faculty members
295 also work in the various hospitals in Boston. The CGA provides special assistance to them,
296 making sure that their research and teaching needs are supported by the university floating

297 licenses, while these licenses are not mistakenly used in the hospitals' operation, which would be
298 a violation of the university site license agreement.

299 **Training Programs**

300 Before the establishment of the CGA, the HMC GIS staff offered hands-on training in
301 both GIS and remote sensing, which were converted into online tutorials. These tutorial materials
302 continued to be available online through the HMC website. In addition, the CGA offers a multi-
303 faceted GIS training program both on the main campus and on the Longwood medical campus.
304 This includes a number of credit courses at the introduction level, the senior thesis level, and the
305 graduate student level, tailored to meet different needs from students in different disciplines,
306 such as social sciences, environmental sciences, engineering, and public health. It also includes
307 non-credit courses, and a series of hands-on training seminars of geographic analysis tools and
308 methodologies open to all Harvard affiliates every Friday during the academic year. Since 2009,
309 the CGA has added a 10-day intensive training program called the Harvard GIS Institute, for
310 faculty and graduate students who wish to learn GIS during the winter or summer breaks. The
311 program is so popular that some applicants have to wait for a year to obtain a seat in it. Software
312 specific self-learning tutorials are easily accessible from the CGA website as well.

313 These training programs and the CGA's technical consultation services feed and backup
314 each other, and combined with the HMC's data service form a balanced support network to users
315 with different needs. Some researchers come to CGA for technical consultation first, but as their
316 projects develop, they realize that it would be more efficient if they themselves can do some
317 hands-on GIS work, thus they sign up for the training, and gradually become more independent
318 in designing and conducting their geographic analysis. On the contrary, some researchers have

319 unrealistic goals in their geographic analysis project at first. After taking the training courses,
320 they realize that GIS is not as simple as just learning to use a piece of software. Their time is
321 better spent on focusing on their disciplinary topics, leaving the geographic analysis work to the
322 CGA staff. Thus they became more frequent users of the CGA analytical services after the
323 training.

324 Many students who took these courses or training programs went on to apply geographic
325 analysis in their thesis or dissertation work. In the past five years, one of the authors who served
326 on the review committee for the Howard T Fisher Prize in GIS¹¹ witnessed significant
327 improvement in the complexity and quality of GIS work among the award applicants. This
328 observation is shared by all members of the review committee.

329 **Consultation and Help Desks**

330 The CGA has designated office hours when users can walk in and ask for help (Figure 5).
331 Questions addressed at the CGA help desks include where to find certain data, how to do certain
332 analysis, which software tool is most appropriate for certain projects, how much to budget for
333 geographic analysis in certain grant proposals, which GPS model meets certain field work needs,
334 how to design the database or web service for certain projects, how to quickly learn certain GIS
335 skills, and many more. The CGA help desks on the main campus and the medical campus,
336 together with the virtual help desk (24 hour response time by email and/or phone) served over
337 100 inquires per month on average. Users range from faculty members, research associates, post-

¹¹ The Howard T Fisher Prize in GIS website:

http://gis.harvard.edu/icb/icb.do?keyword=k235&pageid=icb_page190018

338 doctoral fellows, graduate and undergraduate students, and staff, to visiting scholars. Among
339 them, graduate students are the most numerous help desk users.

340 **Figure 5 The CGA Front Office and Help Desk**

341 The HMC reference desk gets GIS and digital data requests daily, and the questions tend
342 to be from patrons who may not even know what GIS is or how it can help them. There are no
343 set hours for GIS-related questions, since patrons are just as likely to be looking for a road atlas
344 as for GIS help. Patrons with time consuming requests are often asked to schedule an
345 appointment, and complex projects are referred back to CGA. Most GIS interactions are with
346 undergraduates, but there are also many graduate students who are introduced to GIS for the first
347 time at the HMC reference desk.

348 **Analytical Services**

349 In some cases, a help desk visit could lead to a follow up consultation session, which
350 could lead to a more dedicated service project. At this capacity, the CGA operates like an
351 internal consulting firm, working with the users to define project scope, specify deliverables,
352 estimate risks and uncertainties, plan alternatives, set schedules and milestones, and calculate
353 service costs. Most of such service projects are completed internally by CGA staff, but a portion
354 of them involves outsources services too. For those cases, the CGA staff would identify
355 appropriate external service providers, negotiate service contracts, communicate technical
356 requirements, perform quality assessment and quality control on their deliverables, and manage
357 the external contracts for the end users. Work requiring external services are usually labor
358 intensive (such as digitizing features from historical maps), or highly specialized (such as
359 developing a software module to plug into certain CGA systems). Another type of CGA service

360 supports teaching directly, where the CGA staff would develop and deliver a customized GIS
361 training module for a non-GIS class or research team. Such training is usually followed up by
362 more hand-holding when the students or researchers start to use what they have learned to apply
363 geographic analysis in their course work or research project. The authors will discuss more
364 specific geographic analysis service cases in support of medical research at Harvard in the next
365 issue of this publication.

366 **Technology Monitoring**

367 With the rapid evolution of the geospatial technology, many faculty and students find that
368 even after investing significant amount of time learning the GIS tools, it is still very hard to keep
369 their skills and knowledge up to date with the changes. They could be proficient with one version
370 of a popular software, or one model of a popular equipment, but a couple of years later, they are
371 at a loss again when facing the new versions, new models, new data formats, and new
372 visualization trends. The CGA staff serves as the geospatial technology steward for the Harvard
373 GIS user community, monitoring, evaluating, reporting, selectively acquiring new technology
374 products, and introducing new methodologies, standards, architectural platforms, and technology
375 services. They attend the major geospatial conferences periodically, subscribe to the popular
376 technical newsletters and journals, and remain active in the geospatial professionals' circle. In
377 return, they publish a monthly newsletter to over 1000 readers, and maintain the CGA website
378 which averages over 1000 hits daily.

379 The CGA also hosts annual conferences, providing a forum for the Harvard users to
380 exchange ideas and experiences with invited scholars on geospatial technology and its
381 application in designated fields. Conference themes range from GIS, remote sensing,

382 geocoding/georeferencing, spatial-temporal modeling, technology applications in the study of
383 religion, global temporal gazetteer development, and web mapping. Another technology forum is
384 co-sponsored by the CGA and the Harvard grass-root technology group called ABCD-GIS¹². The
385 monthly brownbag seminars bring out speakers from the Harvard GIS professionals community
386 and other universities, companies or government agencies. It is open to the GIS community at
387 Harvard and beyond.

388 **Web Map Services**

389 Anyone who has kept an eye on the geospatial technology trend in recent years would not
390 have missed the wave of web services. In addition to the HGL discussed earlier, the CGA has
391 developed and continues to enhance a number of web mapping applications, engaging in a
392 variety of technology platforms from ArcGIS Server (ESRI, 2008), to GoogleMap API, to
393 complete open source systems built on OpenLayers, MapServer and PostgreSQL (Lewis and
394 Guan, 2010). Among them are several applications in support of medical research, such as the
395 Surgical Safety Web Map and the Emergency Department Web Map. These applications will be
396 discussed in detail in the next issue of this publication.

397 The WorldMap is an example of collaboration between the CGA and the HMC at the
398 system development and collections levels. It was built to assist academic research and teaching
399 as well as the general public with an open source system that allows for discovery, investigation,
400 analysis, visualization, communication and archival of multi-disciplinary, multi-source and
401 multi-format data, organized spatially and temporally. The first instance of WorldMap was

¹² The ABCD-GIS group website: <http://www.abcd.harvard.edu/harvard/groups/abcd-gis/>

402 focused on the continent of Africa, called AfricaMap (Lewis and Guan, 2010)¹³. Since its beta
403 release in November of 2008, the framework has been implemented in several different locations
404 with different research focuses, including metro Boston, East Asia, Vermont geological sites,
405 Harvard Forest and the city of Paris. These web mapping applications are used in courses as well
406 as by individual researchers. Figure 6 shows the Malaria seasonal variation overlaid on
407 population density in AfricaMap.

408 **Figure 6 Malaria Seasonal Variation Overlaid on Population Density in AfricaMap**

409 Some data layers presented in the WorldMap systems are contributed by the HMC, and
410 some data layers acquired by these systems are in turn submitted to the HMC for long term
411 archiving. Moreover, critical data layers in these systems are included in HGL, and the
412 download function calls an HGL download service directly. This cross-system integration avoids
413 the duplication of data storage and system development, offering the users a seamless experience
414 utilizing both systems behind the scenes. Further integration is under development which will
415 allow for cross-serving of data layers between the two systems as web map services (WMS) and
416 web feature services (WFS).

417 **Conclusion**

418 The HMC, with a history of nearly two centuries, and the CGA, with merely 5 years of
419 existence, form the core components of the infrastructure in support of geographic analysis at
420 Harvard University today. Their success relies on collaboration, not only between each other, but
421 also with various research support organizations in the schools and departments throughout the

¹³ AfricaMap website: <http://africamap.harvard.edu>

422 University (Figure 7). The CGA's Technical Advisory Committee includes members from not
423 only the libraries, but also the Harvard-MIT Data Center, the Institute for Quantitative Social
424 Sciences, the Instructional Computing Group of the Faculty of Arts and Sciences, the Computer
425 Resources Group of the Graduate School of Design, the Harvard School of Public Health, the
426 Harvard Planning & Allston Initiative, FAS Department of Earth and Planetary Science, and the
427 School of Engineering and Applied Sciences. Each of these organizations provides infrastructure
428 support to their department, school, or the University at large, and covers different technology
429 domains, such as statistical analysis, database management, web design and development,
430 computer aided design, three-dimensional visualization, and system engineering. Geospatial
431 technology intertwines with these technology domains, and the CGA receives support from these
432 organizations while providing support to them at the same time. The CGA staff could be an end
433 user of their service in one project, a collaborative partner in another project, and a subject matter
434 expert offering consultation service to them in yet another project. For example, the CGA is an
435 end user of the Dataverse Network (DVN) for data archiving and dissemination; the CGA staff
436 and the DVN development team are working together to explore methodologies for mapping the
437 study cases in the DVN; and the CGA built a geographic location finder tool for the DVN users
438 to populate the latitude and longitude fields in the metadata when they submit data to the DVN.

439 **Figure 7 The institutional relationship among CGA, HMC and other organizations**

440 These multi-dimensional collaborations form a support web, providing many places and
441 methods for patrons to start their projects with the proper technology support, and to be guided to
442 geographic analysis if their projects call for it. This support web also ensures that the people in
443 each place work together, each according to their own strengths, to get the patron the help he

444 needs. It avoids redundant capacity building, which is critically important in the current financial
445 hardship. For example, the CGA does not invest in long term data repository. All geospatial data
446 that are worth archiving are handed over to the HMC to be properly cataloged, loaded into HGL
447 for user download, and archived in the Harvard Digital Repository Service (DRS).

448 Such a collaborative infrastructure is not without challenges. Harvard University has the
449 tradition of being a distributed system, with each organization operating under autonomous
450 terms, described as “every tub has its own bottom.” Many excellent support teams are focused on
451 supporting their own department or school only, with no mandate or capacity to provide support
452 across the administrative boundaries. The CGA’s operational model broke this tradition. It was
453 established to serve the entire University from the beginning. But five years into its operation,
454 the CGA has yet to reach out to all potential users. The demand on CGA’s service is still
455 growing exponentially, almost doubling every year (Figure 8). Outreach and coordination
456 continues to be major tasks for CGA, competing for limited resources with technical projects.

457 **Figure 8 CGA help desk number of tickets (2006-2010)**

458 Moreover, for users who are familiar and satisfied with CGA services, CGA became their
459 “one-stop shop” for technology support. It is often hard for the end user to clearly define their
460 project’s need for the different technical domains. Often times, one project needs data
461 acquisition, database design, web development, geographic analysis, and statistical modeling.
462 The researcher may not be familiar with all the specialty support teams for each of these
463 components. They may rely on CGA, or whichever team that they are most familiar with, to help
464 them define their project scope, identify technology needs, and establish initial contact with the
465 other specialty teams.

466 The CGA's operational model not only bridged among the technical support teams, but
467 also made cross-disciplinary and cross-school connections. People from all parts of the
468 university come to CGA for assistance in finding data, making maps, selecting analytical tools or
469 receiving training. The broad user contacts put CGA staff in a unique position to help make cross
470 disciplinary connections for scholars. An epidemiologist from the Harvard School of Public
471 Health might be looking for the same census data as a political scientist from the Harvard
472 Kennedy School of Government studying violence; and an entomologist from the Harvard
473 Museum of Comparative Zoology may be interested in building the same digital elevation model
474 and hydrologic network as a historian or archaeologist studying ancient trade routes. Through the
475 CGA, some of them became aware of other's work in the same region of the world, made
476 contacts to each other, shared base data and local data sources, coordinated equipment usage
477 (such as GPS), and some even found other's work inspiring to their own research (Guan and Bol,
478 2009).

479 The CGA started with a humble beginning of 3 FTEs and a 2-room office. By the fifth
480 year, it has doubled its annual budget, tripled its staff, and quadrupled its office space. The core
481 funding from the Provost Office allowed for the CGA to offer basic services free of charge to
482 anyone with a Harvard ID, including help desk, non-credit training, and initial consultation
483 service. An educational endowment supports the GIS Institute, and income from service projects,
484 grants and gifts make up the rest of the operational budget. By focusing on serving everybody
485 else across the University, the CGA gradually advanced its own status, despite the financial
486 hardship in the past year.

487 The HMC and the CGA share the same mission of enabling geographic research across
488 disciplines. The quest to building an institutional infrastructure for geographic analysis at

489 Harvard University has just begun. As the geospatial technology evolves, and people's
 490 awareness and expectation increase, both the HMC and the CGA will continue to adapt and
 491 adjust in order to improve efficiency and effectiveness, to better serve research and teaching at
 492 Harvard University.

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