

01 July 2015

Michelle Colby, DVM, MS  
Branch Chief  
Agricultural Defense Branch  
Department of Homeland Security  
Science and Technology Directorate  
Washington, DC 20528

Dear Dr. Colby,

As the Authorized Organizational Representative of EcoHealth Alliance, I am pleased to present you with the enclosed proposal (*Mantle: A Software Platform for the Future of Infectious Disease Biosurveillance and Research*) in response to BAA 15DHS-001-TTA-3-0009-I. I am certain you will find the information in line with your needs. The proposal covers the following key points:

- Establishes universal biosurveillance data standards
  - Develops a novel open-source and open access (free to all users) cloud-based One Health biosurveillance platform that can fuse multiple data streams for research and analysis in near real time
  - Develops a friendly and efficient user interface for researchers, policy makers, and the general public (including corporate entities) to interact with worldwide One Health biosurveillance data and to use predictive models developed by EcoHealth Alliance
- EcoHealth Alliance leads cutting-edge research into the critical connections between human and wildlife health and delicate ecosystems. EcoHealth Alliance is dedicated to developing solutions that promote conservation and prevent pandemics.

Thank you for the opportunity to serve you. I look forward to meeting with you again after you have reviewed our proposal,

Sincerely,



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cc: Dr. Andrew Huff, Dr. Peter Daszak, and Mr. Harvey Kasdan



## Cover Page

1. **BAA Number:** BROAD AGENCY ANNOUNCEMENT (BAA) 15DHS-001 National Bio- and Agrodefense Facility Transition Research Project on behalf of Department of Homeland Security Science and Technology (S&T) Directorate
2. **Title:** *Mantle: An open-source and open-access software platform for biosurveillance and infectious disease research*
3. **Prime Offeror:** EcoHealth Alliance
  - a. **Subcontractors:**
    - i. ProMED
    - ii. International Society for Disease Surveillance (ISDS)
    - iii. Distributed Information Technologies Inc.
    - iv. Clango Inc.
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6. **Duration of Effort:** 3 years

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## Executive Summary

Mantle is a free and open-source project, developed under the Apache License 2.0, with all code hosted on GitHub. Data that are made publicly available by contributors will be open access (free to any other Mantle user). Infectious diseases cause great harm to human and animal health across the globe. Furthermore, the unforeseen emergence of infectious diseases has destabilized economies, harmed biodiversity, and reduced the capacity of public health systems to respond to future infectious disease threats. Events like the 2014-2015 Ebola epidemic highlight that the international health community lacks either the sheer capacity or the appropriate distribution of resources to respond to outbreaks when and where they first occur. The One Health approach to public health proposes that human interaction with ecosystems not only contributes to ecosystem degradation (harming the health of these systems), but also puts human, plant, and animal populations at risk for subsequent outbreaks of infectious diseases. By acknowledging that human, animal, and ecosystem health are linked, One Health proposes an interdisciplinary and holistic approach to solving problems. Despite a movement towards One Health research, the infrastructure to manage the information and datasets that are ever growing in size and complexity remains unsuited to the magnitude of the problem. The desire for single entities to control information, to achieve greater personal and organizational wealth and power, directly opposes the intended goals of biosurveillance and One Health. Open access and open source software platforms are needed to address these complex One Health problems.

Mantle is an open-source web platform designed for the storage, sharing, and visualization of One Health biosurveillance data and is designed to meet the needs of a wide variety of users. One Health researchers in the field or the lab can upload datasets to Mantle in a variety of commonly used formats to an intelligent database where they are stored in a unified system for easy download and analysis. Users of Mantle can set fine-grained sharing and privacy controls on uploaded datasets to share or protect their data. Once in Mantle, users can examine datasets in a number of views appropriate to their content, including tables, maps, and charts. Additionally, Mantle's intelligent storage layer can display datasets from different data sources alongside one another and save and export combined datasets. Users with export privileges can download data in a number of formats for use with external software like SAS, R, and ArcGIS.

Mantle's users can belong to organizations and teams, and individual datasets can be grouped together into larger projects, all with group-level access permissions. These features enable scientists to collaborate across geographic, institutional, and disciplinary boundaries to accomplish large-scale data collection efforts not otherwise possible. Mantle also includes a number of open-access datasets from partners and biosurveillance data streams that are available for users to combine with their own data or content.

Mantle will uniquely provide free access to high fidelity infectious disease data, which will enable scientists, practitioners, and policy-makers to tackle the world's biggest One Health threats. Furthermore, Mantle will enable faster response to disease threats as data are continuously uploaded, checked, and contextualized rather than waiting for a worldwide crisis. Open access health data and open source biosurveillance software will help One Health research advance, and Mantle will fill a critical gap in emerging infectious disease knowledge and One Health preparedness.

## Proposal

### *Inadequacy of current biosurveillance data management software*

Our ability to avert future public health crises, like those posed by emerging infectious diseases (EIDs) like highly pathogenic Avian Influenza, FMD, and MERS, depends largely on our ability to accurately and rapidly collect, process, and analyze large amounts of information on infectious disease events. Existing software packages for managing the collection, storage, and sharing of One Health biosurveillance and research data are inadequate for this discipline-spanning, collaborative endeavor.

Datasets do exist for a wide manner of events related to disease and health, and can be utilized to inform traditional disease reporting or develop novel biosurveillance methods (Morse, 2012; Hay et al., 2013). In practice, this is limited by the nature of the datasets, which are generally large, complex, and in disparate locations and formats.

Novel approaches to combining, analyzing, and visualizing data can break down these barriers, and hold great promise for finding new solutions to complex global problems. For instance, in the case of inconsistent data for infectious disease datasets, heuristics can be applied to apply appropriate models to best estimate the spatial distribution of risk given the available data (Hay et al., 2013). Even with relatively poor quality data, the information learned from these types of models can direct the allocation of international development resources to improve environmental health, determine where biosurveillance gaps exist, and identify where public health and medical resources should be staged to more rapidly respond to infectious disease outbreaks.

However, even with modeling methods flexible enough to work with a wide variety of datasets, the relevant datasets are generally kept private, inaccessible to scientists and policymakers alike, and in disparate formats such that a single implementation of the data combination and analysis methods is impossible or overly burdensome.

The field of biosurveillance exemplifies these problems. Traditional disease surveillance operates under a model whereby certain diseases were designated “reportable” under International Health Regulations (IHR) (Morse, 2012) or local, state, and federal regulations. Until 2005, the IHR included cholera, plague, yellow fever, and, before its declared eradication, smallpox. These biosurveillance methods are not designed to detect EIDs, however—pathogens either heretofore unseen in humans, that are increasing in incidence, or in range (Jones et al. 2008).

Event-based surveillance systems have begun to monitor other data feeds to respond to potential disease threat indicators, whether of known or unknown cause. Syndromic surveillance monitors streams of data like employee absenteeism and sales of prescription and over-the-counter medication to identify signals suggesting a public health event (Morse, 2012). These signals have not yet predicted an outbreak and are currently best used as an early warning system that supplements the other types of existing biosurveillance systems (Morse, 2012).

Disease surveillance is one of many areas that would benefit from improvements in information management and analytics. USAID and partner organizations have access to vast datasets of disease- and development-related phenomena, including passive and active surveillance on IHR diseases, novel pathogen identification, and emerging infectious diseases. These data are almost entirely spatial in nature: if not explicitly, they at least implicitly describe phenomena occurring across the Earth’s surface and when combined can help identify where

biosurveillance information gaps exist, and assist with resource allocation during disease outbreaks.

A system to host disparate datasets and make them interoperable would enable many new applications in One Health research, allowing, for example, heuristics such as those described by Hay et al. to be applied to the data to generate new knowledge and improve the allocation of resources to combat infectious disease threats worldwide (Hay et al., 2013).

*No existing software product is a complete solution*

Existing tools only partly address the need to collate and combine infectious disease data. For example, USAID's GeoCenter takes advantage of these datasets spatial nature by displaying each on an interactive map, which the user can zoom and pan around to examine the data. GeoCenter is a storehouse of spatial datasets hosted by ESRI. It displays spatial datasets, but is not open access, lacks interoperability, and is not compatible with generally accepted and user-friendly data formats. Most problematically, GeoCenter does not provide the metadata for fields in its' tabular data which makes it very difficult to analyze outside of their systems. Lastly, GeoCenter is prohibitively expensive for many users and users can only download data in ESRI's formats.

Another example, Dryad, is an open-source archive of datasets. It hosts detailed metadata for each dataset, provides DOI numbers for datasets it hosts so that it can associate them with published papers, and provides an interface to search. It also indexes KNB and TreeBASE, two other dataset archives. All three are part of DataONE, and NSF-funded collaboration working toward better data practices in science.

Dryad differs from USAID's GeoCenter in a few ways. It is not specifically designed for any kind of data, but is designed for users to be able to register and upload their own datasets. Both treat datasets as single units, with dataset-level metadata but a lack of sub-dataset-level metadata. Mantle aims to operationalize users' datasets and will uniquely allow the combining and filtering of existing datasets, generating new possibilities for existing surveillance data feeds not provided by Dryad or GeoCenter.

Currently, most One Health analyses are carried out on local machines, and on static datasets, like those downloadable from GeoCenter. Analyses might be carried out in GIS software, whether closed-source like ESRI's ArcGIS or open-source like QGIS and GRASS. Programming languages like R and Python also allow for in-depth analyses to be conducted on spatial data, using custom statistical procedures as warranted. These tools form a crucial part of the tool chain, and the ability to examine and explore datasets with them will be important for the foreseeable future. Mantle will still allow users to download data for analysis in these software applications while also providing value-added products and services for combined datasets.

*Mantle is the solution*

Mantle is an open-source, cloud-compatible platform for storing, studying, and sharing data on infectious diseases across plants, animals, and humans. It is designed to meet the needs of three groups of users: scientists, policymakers, and the general public.

For scientists, Mantle makes datasets portable and connected. Scientists can upload datasets to the Mantle website or collect data from the field using a mobile app. Datasets in Mantle can easily be made entirely private, publicly accessible, or shared with specific users or groups.

Mantle can handle tabular data, and other widely used spatial data formats. Data can be visualized and explored in useful ways, and can be downloaded in the originally uploaded file or in a customizable format for use in analytical software.

Mantle stores metadata—information about a dataset and its contents—using development standards for linked data—namely JSON-LD and WCSV, part of the overarching Resource Description Framework (RDF). Tapping into the emerging semantic web enables richer interactions with datasets, streamlining many common data tasks. Mantle natively understands a number of data types common to One Health data, including spatial and temporal elements, taxonomic names, case counts, and associates these data with published ontologies. However, it also works seamlessly with any numeric, categorical, and textual data.

Mantle is pre-populated with a variety of open-access datasets for common One Health data types, including land cover types, land use change, human population, wildlife population, agricultural animal populations, weather and climate, species ranges, and land use types. User datasets can be visualized alongside these datasets, and they can be exported alongside user datasets for use in analyses. In addition to these, any user-uploaded datasets and biosurveillance APIs marked as open-access can be visualized and exported in the same manner. In contrast, user-uploaded datasets marked as private are secure and confidential in accordance with the level of security indicated or marked by the user. By combining open access data with EcoHealth Alliance's Hot Spot Mapping models and technology, users can predict where diseases are likely to emerge or travel over road, rail, or air travel networks. Thus, Mantle fills a critical knowledge communication gap between scientists in the field, laboratory and public health scientists conducting analysis, and decision makers and emergency response personnel.

Policymakers and decision makers can view real-time visualizations of biosurveillance streams and data feeds in Mantle's dashboards. Researchers can upload datasets representing the output of models built in other analytical software, which can be shared with policymakers, and policymakers can also view and interact with the output of custom-built modeling modules to view timely and meaningful summaries of public health data feeds. Potential use cases for the general public include browsing day-to-day textual and syndromic surveillance information, viewing the predictions of a one-time study, and monitoring the latest calculated epidemic curve in an outbreak or ongoing epidemic. This use case helps train new One Health personnel in the methods employed in One Health and may help to reduce the general public's panic during outbreak events.

Mantle facilitates crosscutting collaborations between disciplines and institutions. Users can create, manage, and join organizations and groups. Groups of users can access and collaborate on collections of datasets, grouped manually or by specified properties. For instance, users interested in Rhanavirus can view the Global Rhanavirus Reporting System, a collaborative effort by scientists worldwide to aggregate observed cases of Rhanavirus across species and locations (a Mantle prototype). This will significantly improve One Health information management within many organizations and groups.

Mantle is developed as an open source project on GitHub. Users can run their own Mantle servers, which will be able to interface with other Mantle instances using semantic web standards. Mantle's flexibility makes it suited to a spectrum of tasks related to infectious disease data, while it is simultaneously tailored to commonalities and frequent problems in One Health.



## Performance Goals

Mantle will be a novel biosurveillance tool, to address the objectives of Focus Area 3. In Mantle, data are stored and retrieved in a standardized spatial format that does not require the user to significantly clean or convert scientific data, thus allowing Mantle users to rapidly analyze data in emergency situations in near real time. Mantle requires extensive investment initially, however as an open-source and open-access project, improvements to Mantle will be made by users and the scientific community, similar to the software program R. Thus, Mantle is a cost-effective technology to support the monitoring, communication, and facilitation of emerging infectious disease (EID) prevention. Mantle accepts data on a limitless variety of diseases making it more likely to be used on an ongoing basis and improving the accuracy of FMD outbreak assessments alongside of many other EIDs that put humans and animals at risk. Finally, Mantle's open source (free to be edited and examined by the public) and open access (free to all users) format, along with its user-friendly interface will appeal to the general public and scientists alike. Open source and open access software programs like Mantle improves public perception of disease modeling due to complete transparency of the software. Mantle is currently at a TRL 3 and MRL3, but we anticipate reaching TRL 8 and MRL 5 (this work contains both technology and models) by the end of the 3-year project.

We aim to:

- Establish international universal data standards for biosurveillance systems and metadata
- Develop a novel open-source and open access (free to all users) cloud-based One Health biosurveillance platform that combines and integrates disparate data sources in a variety of formats
- Develop a friendly and efficient user interface for researchers, policy makers, and the general public (including corporate entities) to interact with worldwide One Health biosurveillance data
- Enable advanced users to download shared data combined with other open access data layers that are relevant to One Health research and development to answer complex and relevant One Health questions

Performance goals include:

- Back end
  - Create a secure identity and access management system for users and their data
  - Create a system to combine disparate data sources (APIs or uploaded data sets)
  - Refine One Health existing ontologies to improve Mantle's performance
  - Construct a RESTful API for others to ingest or use Mantle
  - Provenance metadata and/or version control
  - APIs to ingest the hundreds of existing biosurveillance systems into a single One Health platform
  - Obfuscating human health and agricultural data, from research or surveillance streams or field based research, to maintain regulatory compliance and privacy when necessary (e.g., HIPAA, SOX, etc.)
- Front end



- Provide a user friendly and simple interface for complex One Health data and systems
- Provide mobile apps for One Health data collection in the field in multiple languages
- Provide mobile apps for users to view analyses and reports on the go in multiple languages
- Develop a centralized secure web portal for users to upload and store datasets, collect raw data, and share datasets with other scientists and the general public
- Provide users with spatial data visualization tools via the web portal
- Provide users with tools to predict the spread of pathogens via multiple modalities based on each specific agent's characteristics

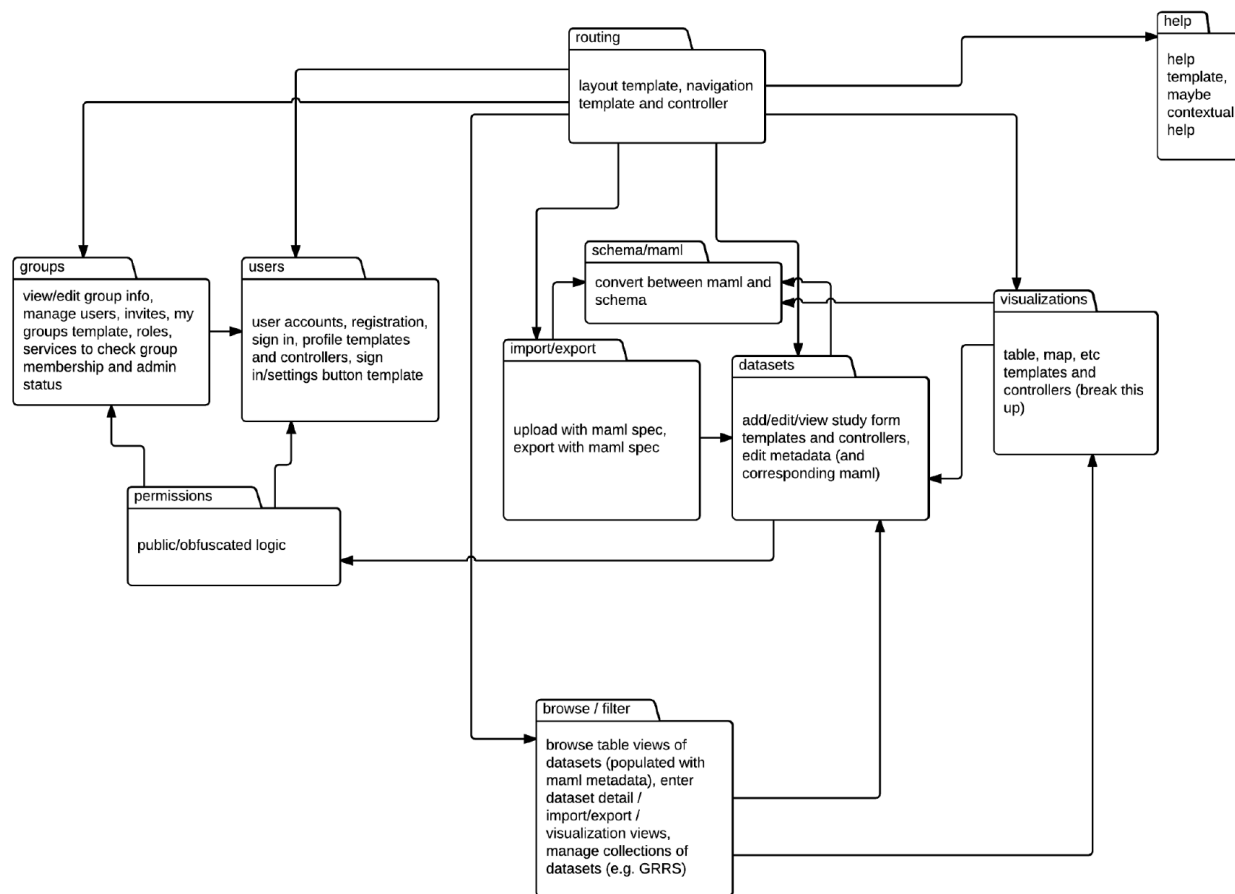
### **Detailed Technical Approach**

Mantle consists of 3 key components. First, there is a back-end cloud-based database that handles the integration of disparate data storage types. Second, there is the front-end graphic user interface that provides the portal for users to input, query, and download data or view pre-loaded analyses (mobile and web apps), and spatial emerging infectious diseases models (for 162 infectious diseases initially). Finally, there is a mobile application to aid Mantle users in collecting and instantly uploading data to the cloud-based server to expedite One Health disease research and development.

#### *Mantle database*

Mantle will use the Resource Description Framework (RDF), which is a standard data interchange model for web-based applications. Mantle will use XML syntax to define both the relationship between two things and the two ends of any link to accommodate evolving data schemas. These Uniform Resources Identifiers (URIs) will allow Mantle to organize and index data from sources such as tabular data, based on best practices developed by the W3C working group. In the case of a CSV file, all of the columns, rows, and cells are converted to an annotated tabular data model. Mantle will be a Linked Data Platform Resource (LDPR), which is an HTTP resource that can be modified and accessed using HTTP code and is managed through a LDP server (<http://www.w3.org/TR/ldp/>).

Mantle will become a Digital Object Identifier (DOI) provisioner so that hosted datasets can be cited and used in published works. We will likely use DataCite (<https://www.datacite.org/node>) to register DOIs for datasets that are uploaded to Mantle because they use an XML schema. Existing tools such as Dryad currently use DataCite for this purpose. Data will be stored in the cloud hosted by Amazon Web Services. See Figure 1 for a detailed illustration of Mantle's schematic.

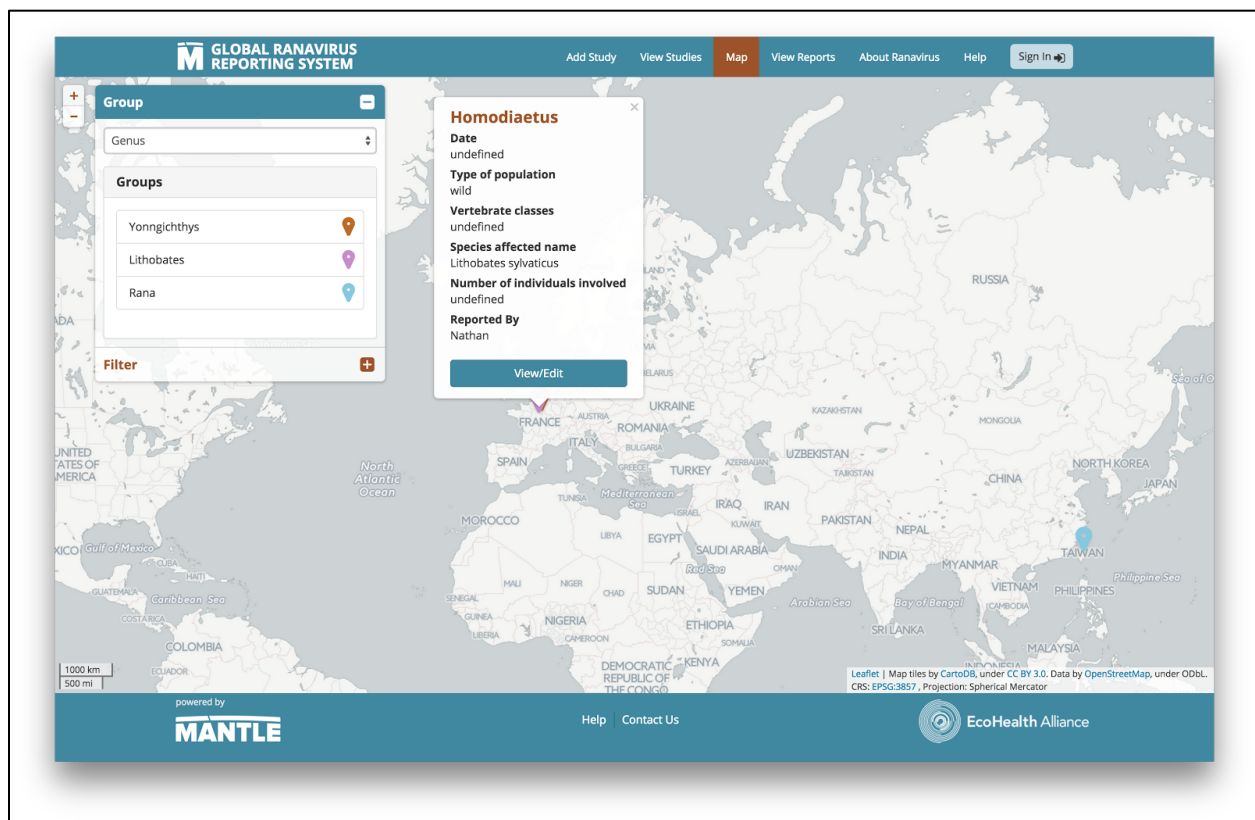


**Figure 1.** Diagram of components of Mantle’s functions, permissions, and data visualizations.

### *Mantle graphic user interface*

Mantle’s web portal will include 6 key pages:

1. The login & registration page;
2. A dashboard and report view which provides pertinent information based on the user’s unique needs or organizational affiliation;
3. Detailed dataset view / management page;
4. A page that enables users to upload and specify it’s metadata;
5. A page that allows users to download open access data across taxa and disease emergence drivers via a simple queries and via selection in a spatial interface (Figure 2);
6. A page that enables users to run models developed and published by EHA under the PREDICT & IDEEAL programs (Emerging Infectious Disease (EID) Hotspots – Hotspots 3, Pathogen Network Travel Analysis – EID Glowurm, Macroeconomic consequence prediction).



**Figure 2.** A screen shot of Mantle’s graphic user interface and web portal. This particular view shows one project, the Global Ranavirus Reporting System, used as a proof of concept for Mantle and is currently being used by the U.S. Forest Service (USDA) and multiple users across the Ranavirus scientific community.

### *Mantle mobile app*

Mantle users will be able to freely download and use a mobile application built for iOS and Android. The mobile application will focus primarily on data entry capabilities for users collecting biosurveillance field data, and will instantly link each data point to a user’s predefined Mantle project and dataset. The mobile application will work best with wireless Internet, but will allow a user to save the data locally until the user can upload data through a cellular network or with wireless connectivity.

## **Statement of Work, Schedule, and Milestones**

The following Statement of Work is supported by a general graphical timeline for the three project phases: Planning, Implementation, and Evaluation and Deliverables (Figure 3).

### *Planning*

1. Task 1: Recruit and hire Mantle staff and students.
  - 1.1. Deliverables: New students and staff on board to aid in Mantle development.
  - 1.2. Completion date: We anticipate completing task 1 by December 2015, with ongoing recruitment of project personnel for various Mantle tasks.
2. Task 2: Mantle kickoff meeting.
  - 2.1. Deliverables: A one-day event that brings together Mantle project managers, a representative from each sub-contract award, and stakeholders from three groups: scientists, policy-makers, and interested parties from the general public.
  - 2.2. Completion date: We anticipate completing task 2 in the late fall/early winter of 2015.
3. Task 3: Construct research, security, and management plans.
  - 3.1. Deliverables: 5 documents that detail the data collection method, web-hosting specifications, research steps, information security protocols, and information management specifications for Mantle development. An outline for a technical document for source code and access information for GitHub.
  - 3.2. Completion date: We anticipate completing task 3 by January of 2015, with input from end-users and stakeholders at the kickoff meeting in task 2.
4. Task 4: User advisory group meetings.
  - 4.1. Deliverables: Initial feedback groups for task 3 research plans and then bi-annual meetings to share progress and obtain specific feedback.
  - 4.2. We anticipate task 4 to be ongoing with bi-annual meetings in the fall and spring of each award year.
5. Task 5: Develop communication and marketing strategy.
  - 5.1. Deliverables: A task list of media outlets and scheduled press releases, and a communications packet (hard copy and electronic) that includes a pamphlet, one-page summary, user instructions, and contact information.
  - 5.2. We anticipate completing task 5 by January of 2016.

### *Implementation*

6. Task 6: Develop application.
  - 6.1. Software testing.
  - 6.2. Field-testing.
  - 6.3. Software refinement (continuous throughout) and stress testing.
  - 6.4. Deliverables: Fully functional database, graphic user interface, and mobile application. We anticipate initial development to take 6-8 months from the award date with software testing beginning in the spring of 2016 (continuous throughout). Field testing will also begin in the spring of 2016 and testing will continue in parallel with development until such a time as user-groups and

research staff are satisfied that the product can be launched for use (target launch is spring of the third year).

7. Task 7: Project management meetings.
  - 7.1. Deliverables: Project managers and representatives from sub-contract awardees will meet by conference or web-based calling bi-annually and as needed for updates and progress reports.
  - 7.2. We anticipate at least bi-annual meetings in October and March of each project year.
8. Task 8: Mantle launch event.
  - 8.1. Deliverables: An evening hosted in New York City to launch Mantle. We will invite all sub-contract awardees, stakeholders, user advisory group members, funders, and donors. The event will involve a demonstration, speakers, and a panel to answer questions.
  - 8.2. We anticipate hosting the Mantle launch event in the spring of year 3.
9. Task 9: Mantle trainings and workshops
  - 9.1. Deliverables: We will post YouTube videos on how to use Mantle and detailing Mantle's source code. We will also host one in-person workshop for users to input datasets and to develop several example modules of data analysis and synthesis using Mantle data. These modules will be available on Mantle.
  - 9.2. We anticipate posting videos in the summer of year 1, the winter and summer of year 2, and hosting the workshop in the winter of year 3. Modules will be posted in the summer of year 3.
10. Task 10: Marketing and Outreach (see Planning, task 5).
  - 10.1. Deliverables: 10 press releases to major U.S. and global cities; posting the Mantle user interface link to public health department websites in academic institutions and state/country health departments; dissemination of communications packet to list servers and key global research and policy contacts.
  - 10.2. We anticipate continuing this task until the final project date.

### *Evaluation and Deliverables*

11. Task 11: Reporting
  - 11.1. Deliverables:
    - 11.1.1. Peer-reviewed journal articles (4);
    - 11.1.2. Financial reports (annual);
    - 11.1.3. Copyright documents; Progress reports (annual);
    - 11.1.4. Technical reports (3);
    - 11.1.5. Property reports (1).
  - 11.2. We anticipate reporting to continue throughout the project and conclude in the summer of Year 3.
12. Task 12: Attend regional, national, and international conferences to share results
  - 12.1. Deliverables: Project staff will disseminate research findings and conduct outreach on Mantle capabilities at conferences and agency meetings.
  - 12.2. We anticipate attending at least 3 conferences in the fall/winter of years 2 and 3.
13. Task 13: Analyze user traffic and data uploads
  - 13.1. Deliverables: User traffic analysis reports (2), and summary of data uploads (2).

13.1.1. We anticipate preparing reports in the spring and summer of year 3 to evaluate progress after the launch date.

14. Task 14: Annual audit

14.1. Deliverables: 3 Annual audits

14.2. We anticipate delivering the annual audit by May of 2016, 2017, and 2018.

Mantle Timeline		Base Year				Option 1				Option 2			
		Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
Planning	Recruit and hire PhD students	x	x										
	Recruit and hire software developers	x	x										
	Conduct Mantle kickoff meeting	x	x										
	Construct data collection plan	x	x										
	Conduct user advisory group meeting	x		x		x		x		x		x	
	Construct web hosting development plan	x	x										
	Construct research & development plan	x	x										
	Information & cyber security plan	x	x	x									
	Establish data & information management plan	x	x	x									
	Establish marketing and communication strategy	x	x	x									
Implementation	Develop application	x	x	x	x	x	x	x	x	x	x		
	Software testing			x	x	x	x	x	x	x	x	x	
	Field test application			x	x			x	x	x	x		
	Project management meetings	x		x		x		x		x		x	
	Software refinement and stress testing					x	x	x	x	x	x	x	x
	Host a Mantle launch event											x	
	Mantle training and workshops				x		x		x		x		x
	User focus groups and feedback			x	x	x	x	x	x	x	x	x	x
	Marketing and outreach			x	x	x	x	x	x	x	x	x	x
Evaluation and Deliverables	Prepare peer-reviewed journal articles				x			x	x			x	x
	Attend regional, national, and international conferences to present results		x			x	x			x	x		
	Financial reports	x	x	x	x	x	x	x	x	x	x	x	x
	Copyright (no patent required as open source open access application)				x				x				x
	Progress & technical reports		x				x				x		
	Property reports				x				x				x
	Analyze user traffic, user accounts, and data uploads									x	x	x	x
	Annual audit			x				x				x	

**Figure 3.** Planning, implementation, and project evaluation and deliverables for Mantle.

## **Deliverables**

### *Mantle planning documents*

Mantle planning documents will be complete 60 – 90 days after the effective date of the award. These documents will outline specific research tasks, security protocols, database architecture, mobile and web application testing procedures, and long-term data management information.

### *Mantle database*

The Mantle database structure will be completed approximately two years after the effective date of the award, and launched within 3 years after the award. Data are stored and retrieved in a standardized spatial format that does not require the user to significantly clean or convert scientific data. These infectious disease data are then stored where the user can decide whether to hide, share with spatial obfuscation, or to completely share with other users in the community. Users are then able to rapidly identify relevant publications, scientists, and host nation partners based on location in maps and tables, rather than by traditional literature reviews via taxonomic description or through social networks.

### *Mantle user interface*

The user interface will be completed approximately one year after the effective date of the award, and launched along with the database two years after the award. The web-based interface enables users to quickly visualize infectious disease data in tables, graphs, and maps and shares this information with partners internationally.

### *Mantle mobile application*

The Mantle mobile application will be completed approximately one year after the effective date of the award, and launched along with the database and user interface two years after the award. The mobile application will allow users to collect and upload data to Mantle projects in real time.

### *Mantle training videos and workshop*

The Mantle training videos will be complete approximately two years after the effective date of the award. These videos will include detailed step-by-step instructions for uploading data, exporting data, using the spatial data viewer, and viewing existing models and analyses. The workshop will gather interested users to develop modules for distribution via Mantle such as the Global Coronavirus Reporting System. This workshop will be held in the winter of the third project year.

### *Mantle reports*

Mantle reports will include technical documents outlining the specifications of the database and mobile application code and architecture, ontology, syntax, and peer-reviewed papers on Mantle development and implementation. These documents will be prepared two years after the effective of the award.



### *Mantle outreach materials*

Mantle outreach materials will include a pamphlet, one-page summary, how-to guides, and press releases. These materials will be available online and in hard copy format. They will be complete two years after the effective date of the project award and disseminated during year 3.

## **Management Plan**

Building on over 40 years of groundbreaking science, EcoHealth Alliance (EHA) is a global nonprofit organization dedicated to protecting wildlife and safeguarding human health from the emergence of disease. The organization develops ways to combat the effects of damaged ecosystems on human and wildlife health. Using environmental and health data covering the past 60 years, EHA's scientists created the first ever global disease hotspots map that identified at-risk regions, to help predict and prevent the next pandemic crisis. That work is the foundation of EHA's rigorous, science-based approach, focused at the intersection of the environment, health and capacity building. Working in the U.S. and more than 20 countries worldwide, EHA's strength is founded on innovations in research, training, global partnerships, and policy initiatives.

EHA is a partner of the USAID Emerging Pandemic Threats PREDICT program, a \$75 million effort focused on predicting and preventing pandemic diseases. PREDICT is building a global early warning system to detect and reduce the impacts of emerging diseases that move between wildlife and people (zoonotic diseases). PREDICT has developed a SMART surveillance method (Strategic, Measurable, Adaptive, Responsive, and Targeted) that accounts for the fact that zoonotic pathogens, like influenza and MERS, are responsible for the majority of emerging infectious diseases in people, and that more than three quarters of these emerging zoonoses are of wildlife origin. The SMART surveillance approach is designed to detect novel diseases with pandemic potential early, giving health professionals the best opportunity to prevent emergence and spread. It also targets sentinel animal species at active human interfaces in hotspot regions to improve surveillance efficiency.

The PREDICT team builds on a broad coalition of partners to develop the global capacity to monitor diseases at the animal-human interface and develop a risk-based approach to concentrate these efforts in surveillance, prevention, and response at the most critical points for disease emergence from wildlife.

### PREDICT project objectives:

- Assess local surveillance capacity;
- Implement targeted and adaptive wildlife disease surveillance systems;
- Develop and deliver new technologies to improve efforts close to the source; and,
- Use cutting-edge information management and communication tools to bring the world closer to realizing an integrated, global approach to emerging zoonotic diseases.

*EcoHealth Alliance* will be the primary organization leading this project with Dr. Andrew Huff as the project lead. EcoHealth Alliance leads cutting-edge research into the critical connections between human and wildlife health and delicate ecosystems. With this science we develop solutions that promote conservation and prevent pandemics. EcoHealth Alliance pioneered the field of conservation medicine, a discipline that addresses the link between

ecological disruption of wildlife, livestock, and human health and survival. EcoHealth Alliance is committed to unifying biodiversity conservation, ecology and health by its leadership and strategic role with its local conservation partners. Project staff includes software developers, data scientists, social scientists, public health scientists, clinicians, diagnostic laboratory personnel, veterinarians, information and cyber security experts, and administrative support (Figure 3).

Our management plan blends strong scientific expertise in global emerging infectious disease (EID) surveillance, using Agile software methodologies for rapid application development. The project will be managed by our team of data scientists and software developers at EcoHealth Alliance, in consultation with thought leaders in the field of One Health biosurveillance (EHA, ProMED, ISDS), infused with innovative technologies DIT Inc., developers of leading edge, high quality software, and secured by in the information and cyber security experts at Clango Inc.

*DIT*, Distributed Integrated Technologies Inc., creates and supports leading edge, high quality software in the fields of spatial databases, GIS & Mapping interfaces, visualization, 3D data publishing, and technical software development. DIT will be responsible for the scaling development of interactive web models and network analyses for rail, air, and road transportation networks for Mantle. DIT employs an open source development model to foster extended, collaborative communities, and an open source business model to provide flexible, low-cost technical solutions. DIT's services and products include technology integration, software support, consulting, custom application development, and training and productivity tools that leverage our open-source software systems.

*Clango* will be responsible for the security aspects of Mantle. Clango has 15 years experience in identity and access management, anti-fraud solutions, governance, and advisory services worldwide. Clango has deployed numerous identity and access management (IAM) capabilities like user registration and lifecycle management; adaptive and federated authentication; privileged administration and access governance. Clango has worked in finance, healthcare, higher education, and across federal, state, and local governments. Clango uses the IAM framework to assure that authorized identities have access to the right data at the right time.

*ProMED*, the Program for Monitoring Emerging Disease, is an internet-based reporting system that provides fast and reliable news about threats to human, animal, and plant health worldwide. Sources of information include media reports, official reports, local observers, and other confidential sources of human intelligence. ProMED staff screens this information before it is posted to the network that includes over 70,000 subscribers in 185 countries. ProMED personnel contributing to this project include infectious disease doctors and epidemiologists (Figure 3).

*ISDS*, the International Society for Disease Surveillance, works to improve population health by advancing the science and practice of surveillance to support timely and effective prevention and response. The International Society for Disease Surveillance (ISDS) is a 501(c) 3 nonprofit organization founded in 2005 and dedicated to the improvement of population health by advancing the science and practice of disease surveillance. ISDS' membership represents professional and academic subject matter experts in the fields of public health surveillance, clinical practice, health informatics, health policy, and other areas related to national and global health surveillance. ISDS works toward a vision of timely, effective, and coordinated disease prevention and response among a skilled public health workforce through programs that position us at the vanguard of the disease surveillance field.

	EcoHealth Alliance																				ProMED	ISDS	DIT	Clango					
AREAS OF EXPERTISE	Andrew Huff	Peter Daszak	Catherine Machalaba	Kevin Olival	Nathan Breit	Maureen Miller	C. Zambrana-Torrello	Jonathan Epstein	Melinda Rostal	Emily Hagan	Russel Horton	Jonathan Golley	Allison White	Simon Anthony	Noam Ross	Frederico Rosario	William Karesh	Amy Slinge	Toph Allen	Daniel Sullivan	Larry Madoff	Marjorie Pollack	Laura Streichert	Edward Trudeau	Patrick McGeehan	Stelhen Matta	Arun Kothannath	Steven Hawkins	Kamille White
Emerging Infectious Disease Modeling																													
Data Management	X	X		X	X	X	X		X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Informatics	X	X			X	X									X	X		X	X		X	X	X	X	X	X	X	X	X
Modeling and Simulation	X			X	X	X						X	X					X	X				X	X	X	X			
Visualization	X			X	X	X					X	X			X			X	X				X	X	X	X			
Software Development																													
Applications Development	X				X						X	X			X	X		X	X	X				X	X	X	X	X	X
Functionality & Design	X				X					X	X				X	X		X	X	X				X	X	X	X	X	X
Mobile Applications					X					X	X				X	X		X	X	X				X	X	X	X	X	X
Scientific Development	X	X			X		X			X					X	X		X	X	X				X	X	X	X	X	X
Systems Development	X				X		X				X	X				X		X	X	X				X	X	X	X	X	X
Testing & Automation	X				X					X	X				X	X		X	X	X				X	X	X	X	X	X
Cyber & Information Security																													
Application and Systems Development Security	X				X					X						X		X		X					X		X	X	X
Business Continuity and Disaster Recovery Planning	X															X										X	X	X	X
Cryptography					X													X						X			X	X	X
High Availability Systems	X															X		X		X				X	X		X	X	X
Identity and Access Management / Control					X													X						X		X	X	X	X
Laws, Investigation, and Ethics	X																									X	X	X	X
Physical Security	X															X											X	X	X
Security Management Practices	X															X								X		X	X	X	X
Telecommunications and Networking Security					X													X								X	X	X	X
One Health																													
Bacteriology		X						X	X	X				X							X	X	X						
Biology		X	X	X			X	X	X	X				X	X	X	X				X	X							
Biostatistics	X	X	X			X	X	X	X	X			X	X	X				X		X	X	X						
Biosurveillance	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Clinical Laboratory Science		X				X	X	X	X	X				X	X	X					X	X	X						
Environmental Health Science	X	X	X	X			X						X	X	X		X	X	X	X	X	X							
Epidemiology	X	X	X			X		X	X	X			X	X				X		X	X	X	X						
Field Surveillance		X	X	X		X	X	X	X	X			X	X			X	X	X	X	X	X	X						
Food Systems	X		X				X	X	X								X												
Health Systems Research	X	X	X			X	X			X						X	X	X	X	X	X	X	X						
Infectious Disease Ecology	X	X	X	X			X	X	X	X			X	X	X		X		X	X	X	X							
Medicine		X												X							X	X	X						
Parasitology		X						X	X	X				X							X	X	X						
Plant Pathology		X													X						X	X							
Policy	X	X	X	X		X				X			X				X				X	X	X						
Veterinary Medicine		X						X	X								X				X	X							
Virology		X		X				X	X	X				X							X	X	X						
Zoology / Wildlife		X	X	X			X	X	X								X	X			X	X							
Other																													
Cartography	X														X				X										
Data Science	X				X		X				X				X	X		X	X					X	X	X	X	X	X
Geographic Information Systems	X			X			X			X				X	X	X		X	X										X
Governance		X	X			X			X					X			X				X	X	X				X	X	X
Implementation Science	X				X					X					X	X		X	X								X	X	X
Legal and Regulatory	X	X	X			X			X				X				X				X	X	X				X	X	X
Linguistics / Ontology	X				X					X					X			X	X	X	X	X			X		X	X	X
Spatial Databases	X				X		X			X		X	X	X	X	X		X	X					X	X	X	X	X	X
Statistics	X				X	X			X	X	X	X	X	X	X		X	X						X					
Social Science																													
Anthropology						X			X																				
Psychology	X					X																							
Sociology						X													X										

**Figure 4.** Summary chart illustrating areas of expertise and capacity of project staff.

## Facilities

EHA is a 501(c)(3) nonprofit organization that specializes in scientific research on the causes, origins, and spread of zoonotic emerging diseases. EHA scientists have been working on spatial modeling for over 15 years, and on modeling of infectious disease emergence and spread for over a decade. EHA is based in New York City with 10,000 square feet of office space including a meeting room and basic laboratory. A core administrative staff of 11 employees support EHA's scientific team (15 core scientists, 100+ field staff) and are available for work on this project through foundation support. EHA is equipped with 25 networked PCs including ARRA funded International Live Meeting Video Conferencing facilities. EHA has access to multiple servers, server support, and all necessary software on Mac, Linux, and Windows operating systems. Additional computing power is acquired from commercial cloud providers to meet project needs.

EHA has an active program of staff development and this is reviewed and adjusted annually as part of each employee's evaluation process. Specific provisions are made for internal training and external training resources, tuition support programs via a partnership with Columbia University, and active support of staff to spend time in collaborators organizations. All early stage investigators are mentored to provide guidance in research practices, grant management, administration and project management. Financial support from EHA core funds is available to support external tuition, travel to conferences and to conduct joint research in collaborator's institutions. There is no obligation for teaching time at EHA and all research staff are funded for 100% research time; however, there is a provision, through partnership with Columbia University, to enable staff to teach at the undergraduate and graduate level, with monetary support provided by Columbia University. Administration and other staff are supported in their efforts to enhance their careers by the provision of tuition fees for external courses, travel funds for conferences, and time off their core activities.

#### *Facilities at DIT and Clango*

DIT is headquartered in Arlington, VA. DIT's affiliate Clango has an office in Minneapolis, MN. Both offices have their own virtual private networks and phone systems, and share financial and administrative personnel. They also have on-site office managers, lunchrooms, private meeting rooms, and advanced conference facilities including large screen projection systems and whole-room Polycom video conferencing systems. The proposed work will be performed at the Arlington and Minneapolis sites.

DIT has a mixed environment of personal and shared computing platforms. Employees average two computers per person (desktop, laptop, and/or personal home owned system), with each computer typically equipped with multiple multi-core processors, a high-performance graphics card, dual monitors, and 8GB or more of main memory. These personal systems run a mix of Windows, Mac OS X, and Linux operating systems. Shared resources include compilation and testing farms and workstations running a variety of alternative operating systems for testing purposes.

## **Government Furnished Resources**

Mantle does not require information or data from the government to support this work. However, government-collected data at the local, state, and national level can and should be uploaded to Mantle's database or be provided via an API (existing biosurveillance systems) for complete reporting of infectious disease outbreaks and to quantify and predict future emerging infectious disease risk.

## **Cost Summary**

The following Cost Summary is supported by a general graphical timeline for the three project phases: Planning, Implementation, and Evaluation and Deliverables (Figure 3).

### *Planning*

1. Task 1: Recruit and hire Mantle staff and students.
  - 1.1. Subcontracts: N/A
  - 1.2. Man hours: 500
  - 1.3. Consumables: N/A
  - 1.4. Total Cost: \$500,000
2. Task 2: Mantle kickoff meeting.
  - 2.1. Subcontracts: N/A
  - 2.2. Man hours: 1500
  - 2.3. Consumables: N/A
  - 2.4. Total Cost: \$100,000
3. Task 3: Construct research, security, and management plans.
  - 3.1. Subcontracts: N/A
  - 3.2. Man hours: 5000
  - 3.3. Consumables: \$5000
  - 3.4. Total Cost: \$750,000
4. Task 4: User advisory group meetings.
  - 4.1. Subcontracts: N/A
  - 4.2. Man hours: 540
  - 4.3. Consumables: N/A
  - 4.4. Total Cost: \$150,000
5. Task 5: Develop communication and marketing strategy.
  - 5.1. Subcontracts: N/A
  - 5.2. Man hours: 1000
  - 5.3. Consumables: N/A
  - 5.4. Total Cost: \$50,000

### *Implementation*

6. Task 6: Develop application.
  - 6.1. Subcontracts: \$1,105,073
  - 6.2. Man hours: 30,000
  - 6.3. Consumables: N/A
  - 6.4. Total Cost: \$2,575,419
7. Task 7: Project management meetings.
  - 7.1. Subcontracts: N/A
  - 7.2. Man hours: 1000
  - 7.3. Consumables: N/A
  - 7.4. Total Cost: \$151,830
8. Task 8: Mantle launch event.
  - 8.1. Subcontracts: N/A
  - 8.2. Man hours: 500
  - 8.3. Consumables: N/A
  - 8.4. Total Cost: \$150,000
9. Task 9: Mantle trainings and workshops
  - 9.1. Subcontracts: N/A
  - 9.2. Man hours: 1000
  - 9.3. Consumables: N/A
  - 9.4. Total Cost: \$50,000
10. Task 10: Marketing and Outreach (see Planning, task 5).
  - 10.1. Subcontracts: N/A
  - 10.2. Man hours: 2000
  - 10.3. Consumables: N/A
  - 10.4. Total Cost: \$100,000

### *Evaluation and Deliverables*

11. Task 11: Reporting
  - 11.1. Subcontracts: N/A
  - 11.2. Man hours: 5000
  - 11.3. Consumables: N/A
  - 11.4. Total Cost: \$300,000
12. Task 12: Attend regional, national, and international conferences to share results
  - 12.1. Subcontracts: N/A
  - 12.2. Man hours: 1000
  - 12.3. Consumables: N/A
  - 12.4. Total Cost: \$100,000



13. Task 13: Analyze user traffic and data uploads

- 13.1. Subcontracts: N/A
- 13.2. Man hours: 3000
- 13.3. Consumables: N/A
- 13.4. Total Cost: \$200,000

14. Task 14: Annual audit

- 14.1. Subcontracts: N/A
- 14.2. Man hours: 500
- 14.3. Consumables: N/A
- 14.4. Total Cost: \$75,000.60



## **Resumes for Key Personnel**

Please see Appendix A for resumes and *curriculum vitae* of project staff. Figure 3 provides a summary of the project staff's skills provided in Appendix A. The specific program personnel were not individually listed in this document or the budget because we will rotate project staff as necessary to accomplish all of the tasks listed in statement of work.

## **Other DHS Support**

EcoHealth Alliance does not receive DHS support at this time.

## **Assertion of Data Rights**

No claims of proprietary rights in pre-existing data or technology are made, and Mantle will be an open source technology made publicly available via an Apache 2.0 license. One of the major barriers to One Health biosurveillance efforts has been the desire for system owners to profit off of the technology and data provided. At EcoHealth Alliance we want to make the world a better place and we do not want to exploit the technology or data for our own personal gain. Simply, we want to provide tools and technologies that reduce the global threat of pandemics, promote conservation, and make the world a better place.