PART 1

SITUATIONAL AWARENESS

BY DEFINITION, SITUATIONAL AWARENESS IS A SPATIAL and temporal challenge. It requires the ability to comprehend the current status of a situation and project its future status. Only when those criteria are met can leaders confidently make serious decisions about strategies, actions, interventions, and policies.

The pandemic required a level of situational awareness perhaps never before seen in a health emergency. In its sheer breadth and urgency, the pandemic brought about information needs as great as, if not greater than, any world crisis to date, including climate change, terrorism, armed conflict, displacement, and food insecurity. The unique circumstances of the pandemic required innovation around situational awareness on an unprecedented scale.

GIS quickly emerged as a key tool for managing data, visualizing information, and making informed decisions. Map-based dashboards became iconic representations of situational awareness as they tracked the pandemic at every level, but dashboards are neither simple nor the only GIS tool for creating knowledge in an emergency.

The stories in part 1 will take you on a journey beginning in early 2020 with the Johns Hopkins University (JHU) COVID-19 dashboard that opened the world's eyes to the growing outbreak

in Wuhan, China. You'll learn about the practicalities of data collection, the cartographic decisions that contributed to the ominous message of the dashboard, and the architecture and automation considerations as the application (and the infection) went viral. Each decision was vital, including the one to make all underlying data open and available to the world.

The shared data from JHU enabled thousands of governments, health organizations, and businesses to consume the information, add their own local context, and inform their decision-making needs throughout the pandemic. This individualized approach was useful but insufficient. Collaboration among entities making up a state, region, or country became crucial to a coordinated response and required some level of standardization. You'll learn how the US Centers for Disease Control and Prevention (CDC) embraced map-based dashboards as a standard for communicating disease status and trends. The CDC advocated for best practices in reporting case counts, case rates, two-week trends, deaths, hospitalizations, and testing progress. And it supported the inclusion of demographic indicators such as age, gender, race, and ethnicity—showing early insight about the need to monitor for disparate impacts of the pandemic across various population groups.

The CDC project expanded on situational awareness in a way that could reasonably be called surveillance by making it possible to collect state-level dashboard data across the country for analysis and interpretation on a national scale. This effort might be considered a microcosm of the challenge of national and global disease surveillance with its multiple data inputs, required consistency in data elements, and interoperable technology components. In the big picture, public health surveillance constantly captures many kinds of data to derive true situational awareness and initiate subsequent action. One of the promising new programs is wastewater surveillance.

Testing sewage is a method that has been used before for early detection of diseases like polio. It's also been used to monitor levels of opioid drugs and their metabolites in communities and watch for dangerous spikes above baseline. More recently, wastewater surveillance programs have appeared with increasing frequency to detect SARS-CoV-2 and better understand the extent of infections in communities. For example, the University of California San Diego showed the value of geographically targeted wastewater surveillance across its campus. GIS supported the entire automated workflow, allowing real-time updates and immediate intervention. The university's integrated system of viral detection in wastewater, testing, and tracing supported a "Return to Learn" program that provided safe campus housing and allowed students to attend classes in person and conduct research.

Disease surveillance and situational awareness work in tandem as precursors to many other activities in response to the pandemic. One of those activities is contact tracing, which identifies the locations of cases and direction of spread to inform the resource needs for an appropriately scaled contact tracing effort. Through a combination of field mobility tools and dashboards, GIS has been applied to the entire process of case and contact interviews. In part 1, you'll learn how four jurisdictions in Pennsylvania (Allentown, Bethlehem, York, and Wilkes-Barre) received data from their state National Electronic Disease Surveillance System (NEDSS) and created a clear and modern process for managing contact tracing with improved efficiency and accuracy. You'll also learn how to extend traditional contact tracing for an interconnected world.

Nowadays, many of us live lives on the go. We travel by plane, train, automobile, and ship. In doing so, we interact with many strangers in the course of a day—the barista, grocery checker, or fan beside us at a sporting event. The mode and frequency of such travel

stimulates community spread of disease—a stage in the pandemic in which a person may not know where or by whom they became infected. Traditional contact tracing methods are inadequate in this circumstance. Part 1 aims to expand your thinking about the importance of location information as it relates to contact tracing with the introduction of "community contact tracing." Collecting location information intentionally and strategically during a contact tracing interview can provide new insights about high-risk places and encourage new kinds of analytics that offer the opportunity to improve community safety.

Map-based situational awareness, as demonstrated by the JHU dashboard, is an effective starting point for pandemic response. Spatial and temporal information helps answer key questions about what we should do next and where.

GLOBAL DASHBOARD KEEPS TABS ON THE VIRUS

Johns Hopkins University

LESS THAN A MONTH INTO 2020, ENSHENG DONG HEARD the news. A new viral contagion had begun to spread in Wuhan, the capital of China's Hubei province. Dong, a graduate student at Johns Hopkins University in Baltimore, was thousands of miles away from the outbreak's epicenter, but he had studied epidemics and knew how fast they can spread.

Taiyuan, another provincial capital and Dong's hometown, is about 600 miles from Wuhan. That's not exactly next door—it's the same distance that separates New York City and Detroit—but Dong felt concerned for his family's safety.

On January 20, 2020, the first US case of COVID-19 was detected in the state of Washington. For Dong, the coronavirus suddenly seemed much closer.

The next day, Dong met with his faculty adviser, Dr. Lauren Gardner, codirector of the school's Center for Systems Science and Engineering. They discussed the emerging epidemic and decided it was worth a closer look.

Gardner suggested that Dong use GIS to construct an online dashboard, a visualization tool that uses maps and data to monitor unfolding events.

Dong nodded in agreement. "That's my plan."

Civilization engineering

Dong studies systems engineering, a modernized approach to civil engineering for the complex, interconnected world.

"The emphasis is on civilization engineering," Dong said. "It's

basically about the interaction of people with the built environment." The discipline allows Dong to explore ways to combine the objectivity of numeric data with the subjectivity of data visualization.

After completing his undergraduate work in China, Dong earned a master's degree in geography and statistics at the University of Idaho. While interning at the Idaho Department of Health and Welfare, he helped the agency use GIS to collect health-related data.

When Dong first contacted Gardner about the possibility of pursuing a PhD at Johns Hopkins, she was particularly intrigued by his facility with GIS, a skill Dong had honed during an internship at Esri®. He arrived on the Johns Hopkins campus a few months before his program was to start to assist in a study Gardner was coauthoring on measles vulnerability in the United States.

"I immediately jumped into the project and helped her visualize measles risk in a dashboard," he said. Media outlets, including the *New York Times* and CNN, featured Dong's handiwork, a prelude to work that would focus on a much larger health crisis on the horizon.

The data problem

GIS dashboards are typically oriented around a map, with accompanying charts, graphs, or other visuals to contextualize map imagery. But first, a dashboard requires data.

Soon after his meeting with Gardner, Dong gathered the data he needed to launch the Johns Hopkins COVID-19 Dashboard on January 21, 2020. He continued working, mostly by himself, to update data and refine the visualization, driven by a desire to map the outbreak in Taiyuan. "I wanted to see how large the dot was in my hometown and compare it to the dot in the epicenter of the outbreak," he said.

"Ensheng and I were basically the two that started the dashboard, but he was really the mastermind behind it," Gardner said

in a podcast about the science behind the now-famous dashboard. "He's a total whiz with Esri technology and dashboard development."

As cases multiplied around the world, Dong struggled to keep up. He scoured the internet for reliable data, often consulting *BNO News*, a Dutch website publishing COVID-19 data from several nations in table form. In addition to gathering data, Dong had to synchronize it, accounting for the different ways governments classified cases as "confirmed" or "recovering."

Twice a day, he would update the dashboard. "For a month, I barely slept—five hours a day or less," he said.

One reason the work was so labor intensive was that Dong was inputting all the data manually. In February 2020, the ArcGIS Living Atlas of the World team at Esri helped the JHU team with "data scraping," automating the process of importing the data from China. A team of volunteers was assembled from Johns Hopkins to help update and maintain the site.

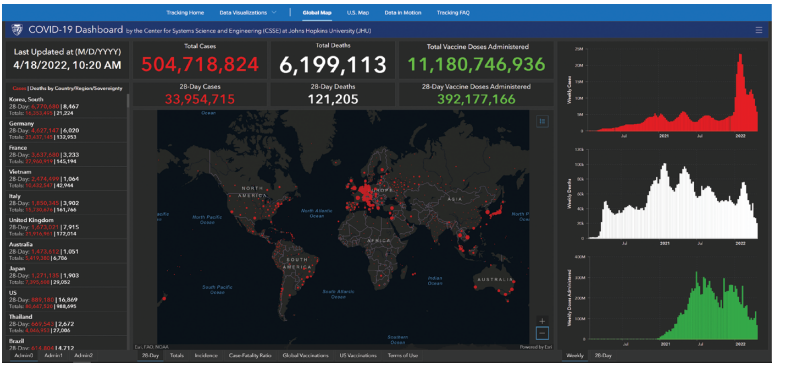
What size the dot?

Soon after Dong began to amass data, he had to confront the questions about how to present it. To emphasize the alarming nature of the pandemic, Dong chose to display bright-red dots over a stark black background. The larger the dot, the greater the number of COVID-19 cases in that region.

Behind each red dot lurks a plethora of choices. A major decision involved how to break down the data for presentation.

As Dong's team adapted the map to provide worldwide data by state and province—and, in some countries, such as the United States, by county—these choices multiplied. The county-level perspective showed the United States blanketed in red dots while other countries might have one large red dot and a lot of blank space.

At the state level for larger countries, Dong broke up one large



The JHU COVID-19 Dashboard has evolved over time, adding more detail to track the spread and toll of the virus.

dot so viewers could see more dots distributed in smaller sizes on the map. "That's a tricky thing for geographers," Dong said. "What's the best size for the dot?"

This kind of map must inform and empower people to act, but it also risks making people lose hope so they see no way out of the crisis.

"We're constantly adjusting the dot," Dong said. "We added a few other maps besides the cumulative and confirmed cases, such as active cases, to clearly communicate the data we were collecting and sharing. If more people in your country are recovering, you refer to that map—the dots are smaller and you feel better."

Directing increasing traffic

Increases in dashboard visitor traffic indicated broad interest in monitoring the disease's progress. "We had at least three crashes," he said. "Each time, it was because of a surge of cases in new locations. I remember that at the end of February [2020], as Italy and other European countries had more cases, we could see that a lot of Italians were jumping on the site to see what was going on."

By mid-March 2020, about the time the World Health Organization officially classified COVID-19 as a pandemic, Dong's team automated updates from all US counties.

What began as an attempt to monitor the outbreak in China has since evolved into one of the world's most trusted sources of information on the pandemic.

By the summer of 2020, the dashboard was receiving between 3 billion and 4.5 billion requests a day. "And they're coming from everywhere," Gardner said. "Most of it is just individuals clicking around on the dashboard, but there are definitely lots of requests for the data that we make available, which other groups are pulling directly into their own internal dashboards and using for policy making."

With the data gathering mostly automated, Dong could spend less time on the site and begin to study the epidemic as the basis for his doctoral dissertation. But he still keeps an eye on the map.

A version of this story by Greg Milner originally appeared as "COVID-19: Inside Look at the Johns Hopkins Dashboard, Keeping Tabs on the Virus" on the *Esri Blog* on July 16, 2020.