# BIP TAKES ON A NASA PROJECT

## How Big Data Can Inform the Way We Keep Bees and How We Can Opt In

BY M.E.A. McNEIL

***So what? That's a fair response to the news that data-gathering projects are coming together. Here's why it matters: The alliance of the NASA hive-weight program and the Bee Informed Project (BIP), together with commercial and open-source contributors, promises to give beekeepers valuable management insight.***

***How? Well, it will take some back stories to get to that, starting some 200 miles above Earth and zeroing down to bee level.***

**NASA**

Images of our planet are continually snapped by NASA satellites -- the Aqua, Terra and polar-orbiter collectively known as Earth Observing Systems. These selfies create pictures that, over time, show the earth "greening up" in spring or "browning down" in fall – dramatically shown in a time lapse video. (**http://climate.nasa.gov/climate_resources/41/**)

Wayne Esaias, as a biological oceanographer at the Goddard Space Flight Center in Maryland, related the satellite-tracked growth of phytoplankton in the world's oceans to climate systems. Esaias is also an EAS Master Beekeeper, and his curiosity was triggered by seasonal changes he was observing with his backyard Maryland bees.

He understood that even the best satellite photos and climate models cannot predict forage bloom without additional on-the-ground observations. Knowing that hive weight reflects nectar flow, he decided that monitoring those weights could provide the needed coordinating observations. To that end, he has gathered and graphed hive weight records for 22 years.

Nectar flow data collected from scale hives has proven to be nearly perfectly in sync with the satellite images. "Honey bees are great data collectors to understand processes of pollination. They sample a very large range of environment," he said. "Scale data can be correlated with the satellite data to show when the nectar flow occurs for large areas of the country. It's extremely valuable. It's rare to have such good indicators." Hive weight is an indicator of hive health: It gives the beekeeper valuable signals, such as when nectar is available in an area, when the bees need supplemental food, and when to harvest honey.

Esaias began to watch an unusual trend, a "greening up" half a day earlier each year. He mustered a national network of volunteer citizen-scientist beekeepers to gather information; they have logged and reported their hive weights to Esaias's NASA site, HoneyBeeNet. There, he saw hive weights peak rapidly with the onset of bloom: "I have seen a hive gain 25 pounds in one day," he said. (**http://honeybeenet.gsfc.nasa.gov/**)

**Jonathan Engelsma demonstrates a hive scale at the Heartland Apiculture Society Conference last summer in Albion, MI. (*Photo Credit: Anne Marie Fauvel*)**

It appeared that the bees were sending a message, so Esaias scoured scientific books and papers for other observations. He found that a Smithsonian botanist had logged records of flowering dates for trees in the Washington, D.C. area – most importantly tulip poplar and black locust, important nectar sources. Those records showed bloom coming earlier as far back as 1970. With that additional information, he determined that bloom in his Maryland area has moved forward by about a month.

For beekeepers, forage is critical. Esaias maintains that if those dates keep creeping forward, crucial plant-pollinator relationships are in danger of getting out of sync. "Flowering plants and pollinators co-evolved. Pollination is the key event for a plant and for the pollinators in the year. That's where pollinators get their food, and that's what determines whether the plant will set fruit," said Esaias. Some plant-pollinator pairs respond to the same environmental cues, but others do not – the pollinator emerging in response to temperature, for example, while the plant flowers in response to snow melt. In addition, a rogue freeze can play havoc with a bee cluster expanding in response to early warming.

**Students examining colonies in the GVSU apiary. Note the early prototype hive scale in the background developed and deployed in GVSU's apiary in 2012. *(Photo Credit: GVSU)***

Esaias's project has been a labor of love for his team of beekeepers tracking hive weights. With his retirement four years ago and with NASA funding for the project ending in 2011, he is still engaged on the sidelines, but he has passed the baton. BIP is now incorporating the HoneyBeeNet data, which features a national map of participating hives. Clicking on a button brings up a list of sites by state, and clicking on a listing shows an apiary and hive weight data or historical data at that location.

Many of the hives in the NASA project are on platform balance beam scales, with reporting done by hand. Others are on electronic scales producing information that needs to be downloaded from the hive monitoring tool and then uploaded to HoneyBeeNet. Esaias designed an electronic hive scale that collects data on site at least every three months. But he has seen that the next step is automatic reporting to the Internet in real time, and, as he hands off the project, that is coming about in several ways.

### The Bee Informed Partnership

Another back story: In the 2007 Congressional hearings on CCD, respected entomologist May Berenbaum testified that "there is an extraordinary paucity of reliable data…." with collection methods "outdated and disturbingly inadequate." Although a survey of honey production had been done for 60 years by the National Agricultural Statistics Service, it excluded small-scale beekeepers, and it did not track migratory practices or health of the bees.

**GVSU computer science graduate students (left to right, Ehsan Valizade, David Qorashi, Sam Serpoosh) who worked with Jonathan Engelsma to develop the BIP Hive Scale Portal. (*Photo Credit: GVSU*)**

The data-gathering group that was formed in response to that need is the Bee Informed Partnership, headed by Dennis vanEngelsdorp, now of the University of Maryland. Whether by coincidence or intuition, he organized by a natural design brought to light by the research of Tom Seeley: Decision making by bees in a swarm follows the same pattern as neurons in the human brain -- a pattern, when applied to human groups, that can produce better results than the best from individual members.

To that end, BIP is a consortium of experts that includes entomologists, agricultural economists, statisticians, extension apiarists, computer scientists, epidemiologists, industry experts, a farm advisor, a stakeholder advisory group and a science advisory board. They have come together to crunch data and come up with better answers than each of their disciplines can do on their own. VanEngelsdorp says that now, with five years of collected information for their Winter Loss Survey and Management Survey, there is enough critical mass for statisticians to analyze for significant results.

The goal, writes vanEngelsdorp, is to "increase the number of beekeeping operations engaged in sustainable practices, decrease risks associated with unneeded antibiotic and pesticide use, and increase beekeeper profitability…Which practices or combination of practices are proving effective at minimizing colony losses?" He says that BIP is "not a research project but an extension project using epidemiological and econometric tools to be communicated to beekeepers in ways that enable them to make real-time data-informed decisions."

BIP's Honey Bee Health database is designed with web-based interfaces, allowing, for example, for lab reports to be uploaded into spreadsheets and loss reports to be graphed onto an interactive map. The overall objective is to promote evidence-based best management practices.

A small, enthusiastic and skilled army of BIP field agents, called Tech Teams, offer hive inspections and testing for large-scale beekeepers -- providing further data gathering. The idea grew out of Marla Spivak's sampling work for Northern California queen breeders and now has grown to five teams: Northern California, Pacific Northwest, Midwest, Florida-Georgia, and now Texas. Tech Team members help analyze test reports and management options.

Remote access to a Tech Team, for experienced apiary managers in areas not serviced, can be established through training at the Northern California location. Then the same program of sampling and analysis from BIP can be provided. The teams are managed by Karen Rennich (**usbeesurvey@gmail.com**)

BIP's complex IT operation is managed by James Wilkes, Professor of Computer Science at Appalachian State University. He said, "Beekeepers listen to each other, but there is a limit to what they can learn that way. The idea here is to glean some wisdom out of everyone's experience, sup-

plemented with historic research data, [that we] haven't had before because we haven't looked at this data all at once."

**How It Came Together**

Yet another back story – hold on, they eventually weave together: Jonathan Engelsma grew up in a family of beekeepers. His grandfather was a bee inspector and commercial beekeeper, his father an orchardist, and in high school Engelsma worked at an uncle's commercial apiary. After earning a PhD in computer science he became an associate professor at Grand Valley State University (GVSU) in Michigan. He found a common interest in bees with a biologist at the University, Ann Marie Fauvel, so together they set up an apiary at the campus.

Engelsma's expertise is in mobile computing – backend network software and software for devices such as the smart phone. He and Fauvel decided to use his know-how to build a hive scale that could feed data to a website. To that end, they joined an engineering professor at the University, John Farris. "We involve our undergraduates and graduate students in multidisciplinary real world projects," said Engelsma. The three engaged engineering and computer science students to create the scale and software for a new app.

Farris' engineering students developed a prototype digital scale with off-the-shelf hardware that they powered with a solar panel. Sensors in the scale collect weight, temperature and humidity readings every 15 minutes. The stored data are transmitted by a radio, using Bluetooth technology, to an outside unit such as a cell phone, smart phone, tablet or laptop within wireless range of about 30 feet.

After the scale was engineered, computer science students developed the software with a web portal using cloud technology. It required the beekeeper to visit the apiary at regular intervals to transfer the information from the Bluetooth radio to the web portal.

While this project was unfolding at GVSU, a conversation had started between Wayne Esaias and computer engineers about streamlining information collection for the NASA project. Michael Wilson of the University of Tennessee, working with Wilkes in the BIP consortium, said, "The process in place involved a significant amount of labor. We identified the need for more automated technology and modern network-connected data management. Vendors could develop their own respective API [application program interface] technologies. We would build online resources to accept the data from these API's and display them together."

At that point, in 2013, Fauvel happened to meet Dennis vanEngelsdorp, and they realized that their goals segued. GVSU became the lead in not only transferring the hive weight data to BIP but in creating means for participants to add to it. It was quickly apparent that the University lab could not


**The commercial hive scales are designed to function 24 x 7 year around in all climates. (*Photo Credit: Jonathan Engelsma*)**

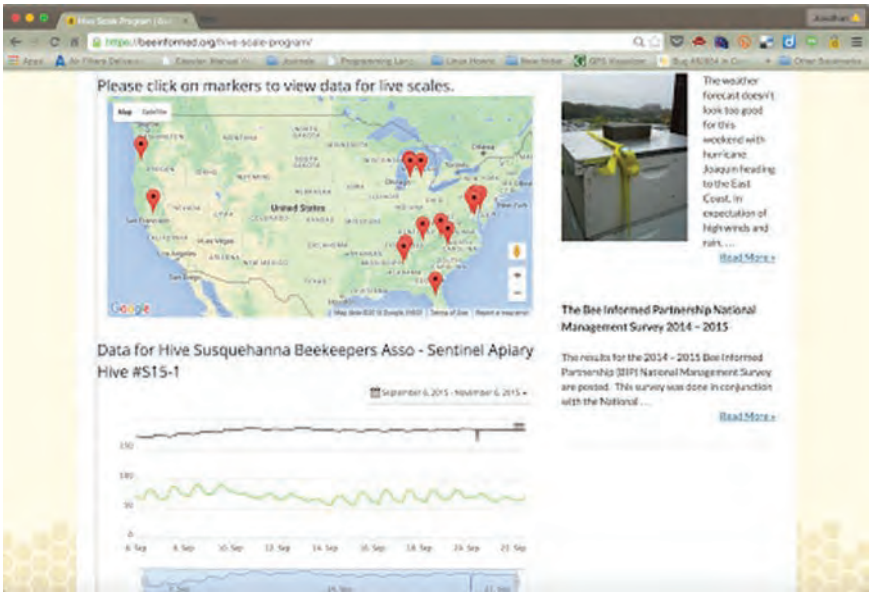
produce and deploy the number of electronic scales that would be required. At the same time, they wanted to design the BIP platform so that any scale could be used.

At this point, an API was developed by the GVSU team to allow scale vendors to integrate their products with the BIP platform. Any manufacturer can receive BIP's scale API documentation and then write custom software to connect their particular device. Information for doing this can be obtained from **AskBeeInformed@gmail.com**.

The site lists the three commercial scales that thus far connect: SolutionBee, from a US company; Arnia, from the UK; and Bee Watch Pro, manufactured in Europe and carried in the Swienty bee equipment catalog. Engelsma's lab has tested them all, and evaluates their pros and cons on the BIP website. "All three scales work and are supported," he said.

The commercial electronic scales that connect to BIP come in two different models: Some have the same electronics as a cell phone. Beekeepers access remotely with a password and can edit data by noting information that would influence hive weight, for example snow load or harvesting. For this, a SIM card and a data plan with a phone company are required.

Then there are those that do not require a phone plan. With these, the beekeeper goes to the apiary and transfers weight electroni-




**Screenshot of the BIP public hive scale map on the main Bee Informed Partnership website.**


**Screenshot of an interactive hive scale graph on the Bee Informed Partnership's Hive Scale Portal.**

cally, annotates it, and then transmits to the BIP portal.

In either case, the BIP program has no manual input. "It makes sense to automate this," said Engelsma. "You're getting samples every 15 minutes. The technology is all there."

With the scale now being manufactured by SolutionBee in North Carolina, beekeepers can access data stored in the scale with a free app from Google Play or the Apple App Store on any Android or iOS device. Temperature and weight graphed over a day, week or month can be viewed live, with the information also available in tabular form. Data can be stored in the Cloud for long-time comparison. That scale is marketed by Brushy Mountain for $525 plus shipping. An optional link makes it possible for a beekeeper to contribute ongoing data from the device to the BIP program, for which there is no fee.

Arnia has the most diverse monitoring system, presenting data with simple, intuitive icons on the user interface. It comes in a box with temperature and humidity sensors, a microphone and a Bluetooth transmitter. A Gateway monitor sends data to their server and displays for the subscriber on any device that connects to the Internet. The hive monitor is $99, the Gateway $199 (one per apiary) and the electronic scale $600. Data is accessed with a remote login system for a monthly subscription fee.

Bee Watch Pro was the first of the trio and costs over $1000. Both Arnia and this model can feed directly into the BIP data base.

Engelsma expects scale costs to decrease with increasing popularity. "I think we're going to see a lot more electronic monitoring of honey bee colonies. It makes sense both for the beekeepers as well as the scientists that are studying honey bee health," he said. His students have already developed an online portal for the hive scales registered for the program. To be included, contact the BIP website. The features of the portal are explained by Engelsma in a video: **https://www.youtube.com/watch?v=KCn--lwjWC8**

A company with the potential to connect is Hivemind, which has a hive scale with voice annunciation and satellite communication hub for $820, with various data plans additional (www.hivemind.co.nz).

"Ideally, we'd like to get to simple inexpensive scales," said Englesma. "We support do-it-yourself projects. We can give a home builder, called in today's parlance a 'maker', the exact same information as a commercial vendor. The API is given to them and they can develop software. We can work with them to make sure that the data can be transmitted. The more [scales] deployed, the more interesting and useful the data."

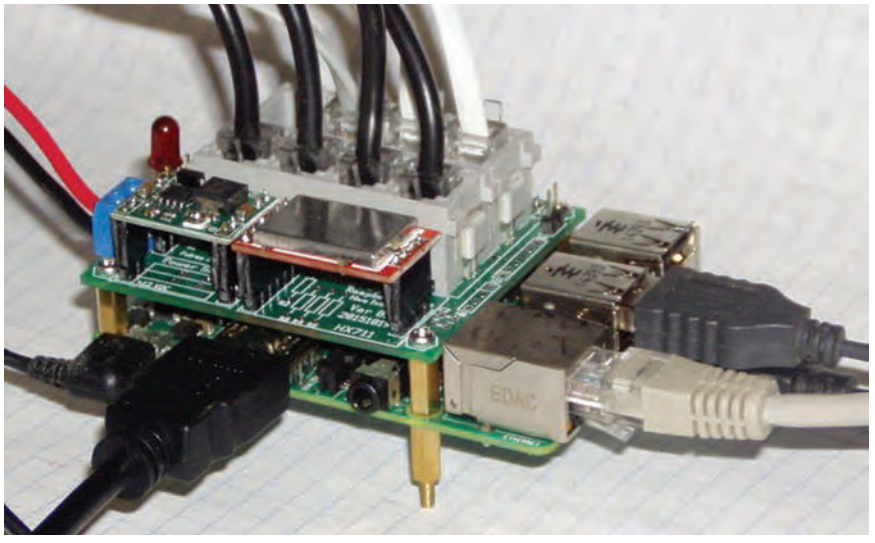
These projects require good computer and electronic skills. There are currently none yet feeding the BIP site, although some individuals are working in that direction. Notable among them is Paul Vonk, the principal engineer, beekeeper and programmer for Hivetool. They offer a hive monitoring kit, to be built with some soldering and technical skill, for $50; it plugs into a Raspberry Pi and a power source. His colleague, engineer Adrian Ogden said, "As an open source project, the entire primary record of the data and research results are publicly available online." (**http://hivetool.net/**)

"Going open source made it easy to get ideas and help from others," said Vonk. Four years ago, they started by connecting recycled computers to commercial off-the-shelf sensors. They have come through challenges, from cables chewed by cows and gophers, manufacturer aberrations, web server implosions. Now they are building a scale and data-acquisition system with the new quad core Raspberry Pi2 computer, a choice made for high performance (sensitivity to a fraction of a pound over 440 pounds) and low cost (a basic online scale will be less than $100, without recurring fees). Other monitoring options are offered beside weight -- including temperature, humidity and hive counters. Data readings will be logged and uploaded to the web every five minutes.

They offer a free download of the Linux operating system and sensor drivers in a single compressed user configurable file at **http://hivetool.org/**. Another site to check out is their Hive Reports at **http://hivetool.net/hivereports**.

"We are working feverously to make a plug-in kit widely available," said Ogden.

For the individual beekeeper, hive weight can be fascinating and useful, according to Engelsma: "It's a practical benefit, whether you're a large commercial operator or if you're a smaller beekeeper, because by sitting at your desk and pulling up a web browser you can see the weight of that honey bee colony out in the field without actually going out there, and that's pretty



**Hivetool's New Developers Kit hardware for the Raspberry Pi platform is undergoing final testing. It is a step toward the goal of a complete turnkey system.**

important. You can see weight decrease as field bees leave, you can see the weight of the nectar coming in, with the night weight loss through evaporation as the honey is processed. In spring you can see a swarm by looking at the weight. By determining the beginning, end, and quantity of nectar flows, beekeepers will be better able to tell when to add and remove supers, when to move hives and where to locate hives to maximize honey production."

A steady decrease in weight can reflect a nectar dearth and signal a need for feeding. A sudden loss of three to eight pounds in a day can indicate a swarm, which may not otherwise be obvious. Knowing that a colony is in the process of requeening would be important information, since disturbance at that sensitive time can cause failure. Or a beekeeper could choose to introduce a mated queen

### Opting In

Once an electronic scale is set up, a beekeeper can enjoy both hive reports and an automatic contribution to the work of BIP. Those who participate are asked three things: First, keep the data coming by collecting it regularly – at best weekly, but at least monthly, since unclaimed data can be written over. Secondly, annotate circumstances that influence weight, such as adding a super. Lastly, choose a level to share information: restricted to other registered users, with a public link embedded in the beekeeper's own website, or by joining Sentinel Apiaries -- the BIP public, interactive hive scale map (**https://beeinformed.org/hive-scale-program/**). For educational value to the beekeeping community, the publically-shared Sentinel Apiary site is the most effective choice for a participant. But privacy is an understandable concern that Esaias encountered, often around sensitive apiary locations. "For BIP there is a need for the public to know," he said. "We have good weather forecasts because the data are freely available." BIP tech team and consortium members are trained to protect confidentiality; their challenge is a commitment to transparency, open access to data, and respect for the personal privacy of participants.

### Hopes and Goals

"The long, long, long term plan is that we will have a general measure of bee health in the United States," said Wilson. He describes his work with John Skinner at UT and James Wilks at Appalachian State University as "big data for bees."

The group processes Colony Loss and Management Surveys, crunches daily reports from Tech Teams, adds lab results from the Real-Time Disease Load Project (where volunteer beekeepers submit samples over six months), and ties in tests for Emergency Response Kits (pest, pathogen and, optional pesticide assays). All this is updated regularly to establish norms, with the goal of making it possible for beekeepers to access comparative information.

### Where it All Is Now

Esaias is glad to see his data continue to be used, but he regrets that his climate change project with NASA will not continue: "It's expensive and it will take funding and researchers involved with climate change research. Very few of them are beekeepers."

He is enthusiastic about future uses for his brainchild with BIP as well as with Hivetool. "Having these two groups going gangbusters, it's great to see," he said, although he would like to see them collaborate. "It would be nice to have all the data in one place. And we will benefit from more data -- more eyes, more sites."

The scale data will be integrated into BIP's site, but at this time hive weights are in one database and the disease load data is in another. "The plan," said Wilson, "Is that once we build a new platform for network-connected hive scales with numerous participants, we could build in analysis similar to that available on Esaias's Honey Bee Net and include the historic data. We are not yet at that point, but we are far along."

**"**As more beekeepers join this effort, the database grows stronger and becomes more useful," said Karen Rennich, who manages the project. "It tracks what is actually happening out there."

**M.E.A. McNeil is a writer, Master Beekeeper and member of the UC Davis Mondavi Center Honey and Pollination Board. She and her husband Jerry Draper live on a small organic farm in Northern California. She can be reached at mea@onthefarm.com.**

### REFERENCES

**Berry, Jennifer, Bee Culture, NASA, HoneyBeeNet, and Bee Informed** Measuring Change, Saving Bees, February 2013.

**Engelsma, Jonathan,** Grand Valley State University, interview 10/30/15

**Esaias, Wayne**, interview 12/10/15

**Lebwohl, Beth, Wayne Esaias**, Interviews, Human World, June 29, 2009

**McNeil, M.E.A.** Boots on the Ground - a radical shift in the interface between research and real world, Bee Culture Magazine, April 2012

**Popovich, Trish**, Students Develop Commercial Hive Sensor, Research-News, July 23, 2014