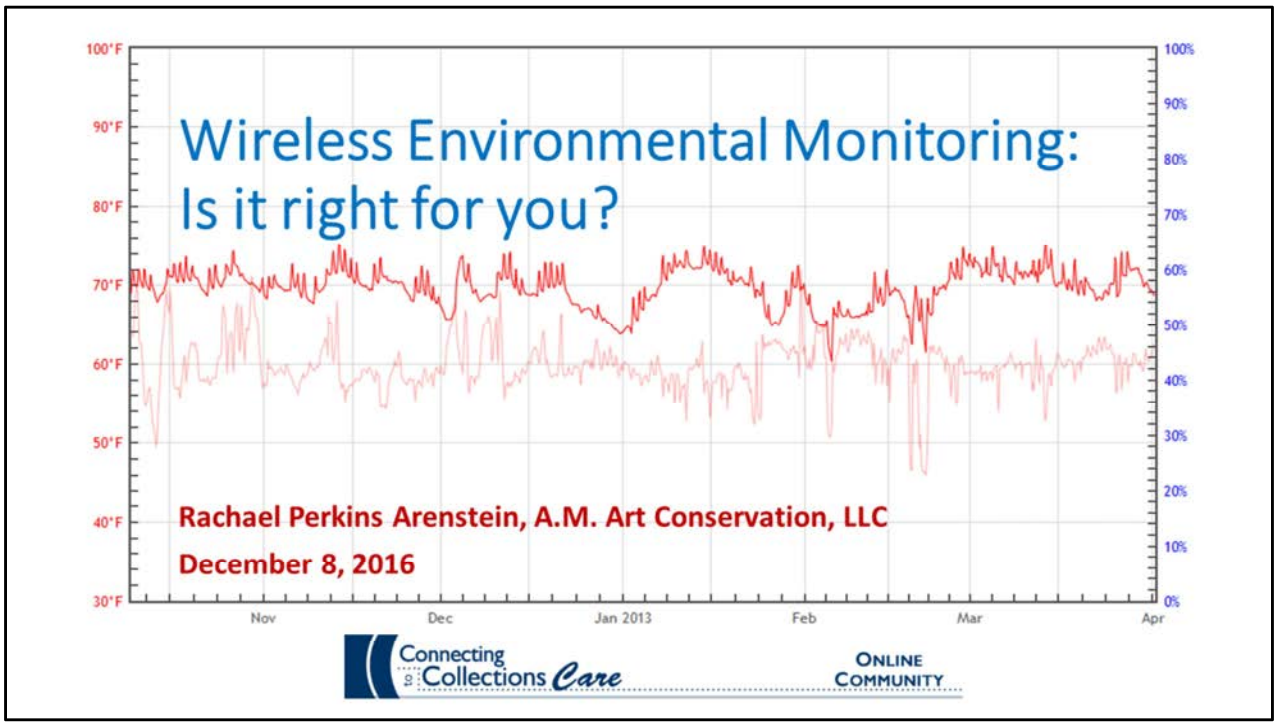
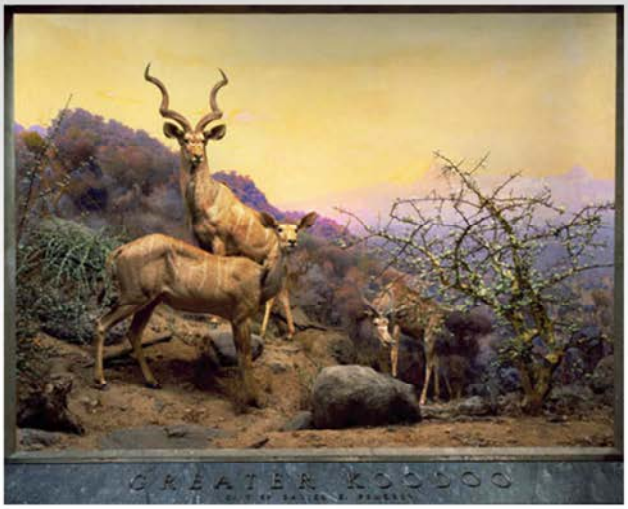


Thank you to everyone who is listening for joining us here on Connecting to Collections Care. I'm pleased to have this opportunity to update the webinar I did on this topic in 2012 because the technology of these products is changing quickly and the question of what equipment is best for monitoring collections is one that we see frequently on various forums and listservs.

Introduction



Conserve O Gram

September 2011 Number 3/1

Comparing Temperature and Relative Humidity Dataloggers for Museum Monitoring

Introduction

Datalogger refers to a battery-powered device equipped with sensors and a microprocessor to monitor and record data such as temperature (T), relative humidity (RH), light, voltage, etc. Datalogging systems usually include propriety software to initiate and set parameters for monitoring, downloading, viewing and analyzing data.

This Conserve O Gram (CO3G) compares several dataloggers and discusses selection criteria focusing on stand-alone loggers (each unit operating independently) rather than networked systems that provide real-time data using wireless or hard-wired technologies. Two accompanying tables list basic hardware specifications (Table 1) and software related issues (Table 2). It updates CO3G 3/3 Datalogger Applications in Monitoring the Museum Environment, Part 1: Comparison of Temperature Relative Humidity Dataloggers, 2001. See also the NPS Museum Handbook, Part I, 4, Museum Collections Environment for other monitoring equipment options.

Methodology

The loggers discussed below are currently the most prevalent in the cultural heritage community. They were selected based on queries and responses posted on several preservation listservs, or were suggested in discussions with manufacturers and distributors. Information was obtained from specification sheets or manufacturers and distributors. Manufacturers or distributors provided demonstration units of each logger. The loggers were run in a series of three environmental chambers at stable temperature with saturated salt solutions of low, mid and high RH. The data was used to evaluate the software and assess logger performance.

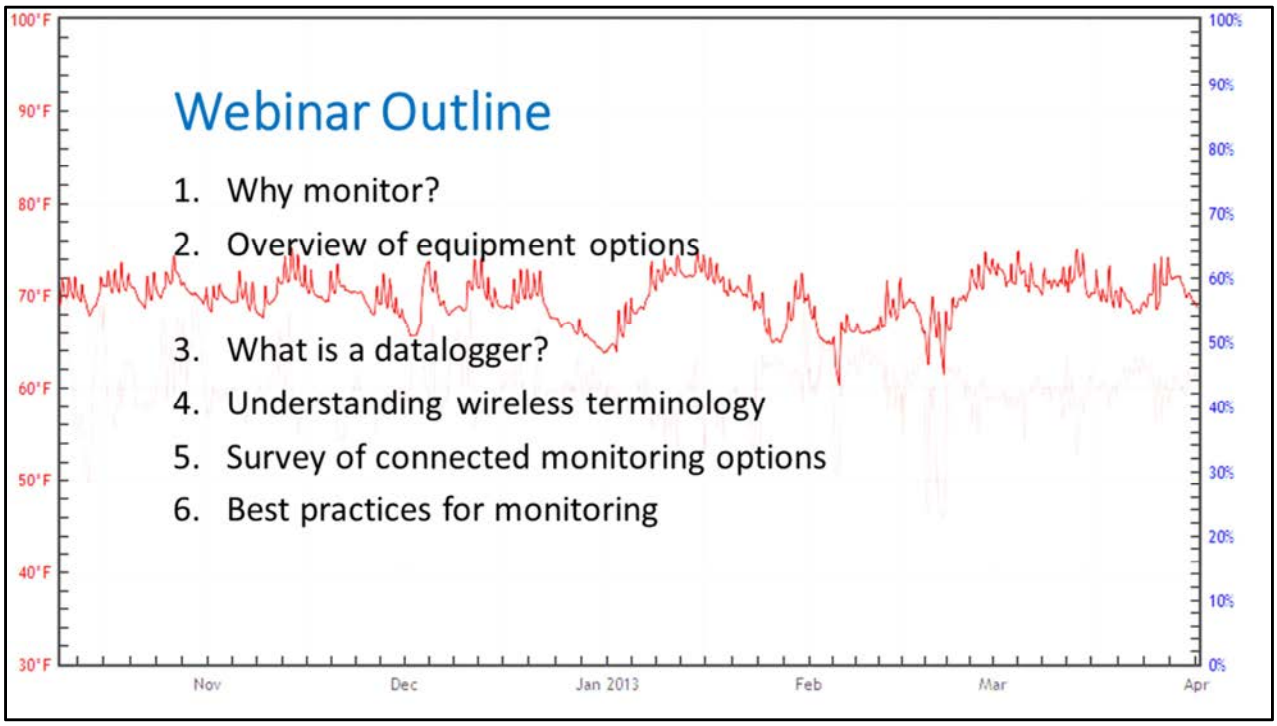
Datalogger Hardware Specifications (Table 1)

Table 1 compares hardware specifications for ten different dataloggers. How to evaluate these specifications is explained below.

Operating Range

The operating range of a datalogger is determined by sensor type and quality. Manufacturers specify range using different terms (e.g. operating, working, reading, or sensor range) but these are not necessarily synonymous. Specification sheets may use one term to indicate the physical limits in which a unit can be exposed, and another to indicate the working range for the sensors. All the loggers listed have functional ranges beyond the temperatures expected in a collection environment and may even function during heat or freeze treatments. A few do not function well at low RH (under 20%). Some

Let me take a moment to tell you a bit about my background so you'll have a sense of where I am coming from. I became interested in this topic during my first job in the Anthropology Department's Conservation lab at the American Museum of Natural History where I was in charge of monitoring exhibit spaces including the incredible dioramas. We had old equipment that was failing and I was tasked with researching what new equipment to buy. I became frustrated pretty quickly because it was hard to understand and compare the specifications sheets for different products as each company used different terminology. But by the end of the project I not only made my choice of new logger but I had the text for what became the first National Park Service Conserve O Gram leaflet on dataloggers. That experience led to a real interest in the unglamorous tasks of preventive conservation as the most efficient way to prevent deterioration. After taking some HVAC engineering classes I fully embraced my geeky love of gadgets. In my private conservation practice I perform treatments for museums small and large and also set up monitoring programs and advise on environmental improvements. So over the years I have had experience picking monitoring equipment for institutions with wildly varied resources. I would also like to mention that in the last few years my partner in crime in datalogger geekiness has been conservator Samantha Alderson at the American Museum of Natural History. Together we updated the Conserve O Gram a few years ago, we've given workshops on the topic and we stay in touch with vendors to keep abreast of the new products that might benefit our field. So that's enough about me, if you want to know more or contact me you can check out the handout for today's program.



Here is what I plan on covering in the next hour leaving time for questions at the end:

1. Because the core audience for the Connecting to Collections Care webinars are small or under-resourced museums I want to give some introductory background information on why monitoring is useful
2. and the broader context of what our options are.
3. But then I'm going to focus on dataloggers and
4. understanding the technology and terminology of wireless monitors. This can get technical but it is important to have at least a familiarity with the terms so you can understand how the products work.
5. Next I'll talk about some of the products that I think are good options for our field.
6. At the end I'll touch on some guidelines for monitoring that I'm frequently asked about and that I think are relevant no matter what equipment you are using.

Why Monitor?

- Document and record the environment
  - Preservation analysis for items or collections
  - Space conditions
  - Seasonal trends
  - Building characteristics
- Basis of management decisions
  - Performance of AHU
  - Malfunctions
  - Improvements and optimization

These days I don't generally have to convince institutions that they should be monitoring. Staff at museums, historic homes, libraries, and archives know that the environment in which we store and exhibit our collections has a direct effect on their long term preservation. But is worth reviewing the ways in which environmental data can be used no matter how large or small you are.

The data you collect is important in understanding the conditions to which your collections have become acclimated. Then you can predict how they will react when those conditions are changed or age if conditions remain the same. Having data on your spaces will allow you to make smart decisions on where you store your pieces even if you are choosing between not ideal options. The data will help you analyze how well your building envelope is acting as the first line of defense in protecting collections and, if you have them, whether your air handling units are performing to the best of their ability. Data is powerful in supporting fund raising efforts to show that you are addressing a documented need whether it be for large projects like upgrading HVAC or small, like purchasing boxes to buffer collections. If you are interested in cutting costs or being ecologically sustainable, then you need this data.

What to Monitor?

We concentrate on T & RH

- Heat and humidity are primary drivers of decay
- Relates directly to HVAC operation

There are other parameters that can be measured and might factor into decision making on the environment. There are loggers that will look at light intensity and/or accumulation. You can also track activity in a space, opening or closing of doors and other variables. But today we're going focus on Temperature and Relative Humidity (or RH). A few of the loggers that we'll be looking at today are able to monitor other parameters and I'll try to mention when it is an option, but the information is also in the spec sheets whose links are given in the handout.

BUT, the goal in monitoring is to have data to actually use. What we are talking about today is just a means to an end. I hope this program will allow you to spend less time in choosing a logger and less time gathering your data – so you ultimately have more time to analyze it and use it to affect positive change. In other words, the data should serve to help you manage your environment – which is a continuous and ongoing process.

Overview of Hardware Options

- Hygrometers
- Hygrothermographs
- Building management systems
- Dataloggers
- Connected systems

I wanted to very briefly review the range of equipment so you have a more complete understanding of your options and where the products we'll be focusing on today fit in.

But first I want to ask a few questions to the audience. Susan can you put up poll questions #1 and #2

Poll Question #1 - Are you currently monitoring temperature and relative humidity?

- Yes
- No

Poll Question #2 - Which of the following equipment are you using for monitoring? (check any/all that apply)

- Hygrothermographs
- Stand-alone dataloggers
- Wireless monitors
- Not sure

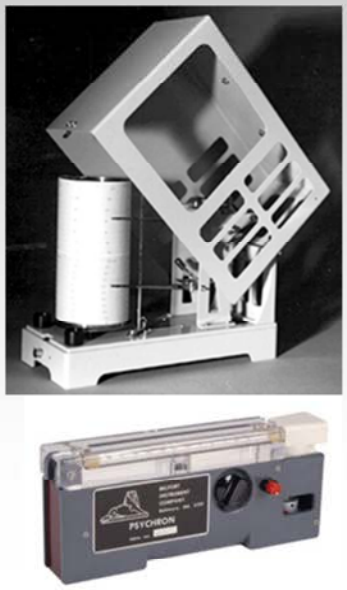
Hardware: Hygrometers

- Traditional monitoring device
- Difficult to examine long-term trends or statistically analyze data
- Precludes use of data in computational tools

We'll start low tech. Hygrometers, are devices for measuring humidity or, thermohygrometers which measure temp and RH are low tech options and they still have a place, albeit limited, for certain applications. There are analog versions like this dial type on top or digital versions like the one shown in the middle. The example on the bottom is called an Arten and it is still popular in museums because it has a redundancy check – with the humidity strip down below to help you determine if the dials are accurate. These units tend to be cheap and of variable accuracy. The analog versions like the dial and Arten units can often be user calibrated. They only provide a spot check – meaning they don't record or log anything. Although the digital versions sometimes record high/low readings. They can be useful for applications like putting in a buffered vitrine (i.e. one with silica gel) so you know when you need to recondition the gel.

Hardware: Hygrothermographs

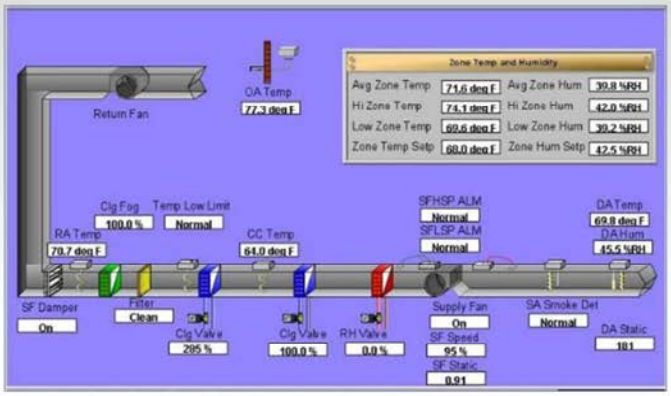
- Traditional monitoring device
- Difficult to examine long-term trends or statistically analyze data
- Precludes use of data in computational tools



A step up from the hygrometers is the hygrothermograph which I assume most of you are familiar with. “Why can’t I continue to use my hygrothermographs?” is something I hear less of these days but the short answer is that you can. Hygrothermographs remain available and, providing they are properly cared for, can provide years of yeoman service with relatively little effort. Hygrothermographs should be calibrated regularly – meaning weekly or monthly depending on when you change the paper charts, since they move out of calibration quickly. But this is easy to do with an aspirating psychrometer (seen in the lower image). As everyone moves towards dataloggers, though, it is getting harder to find the paper charts and pens to use with hygrothermographs. Mostly the downside is that it doesn’t allow you to easily analyze your data statistically to get a sense of the bigger picture. It is like the difference between a flip phone and a smart phone. It can do the job but doesn’t give you all the groovy features that you know are now available. I cannot really recommend hygrothermographs anymore given how easy and cheap dataloggers are these days. And anyone who is such an avowed Luddite is probably not on this webinar anyway!

Hardware: Building Management Systems

- Separate, proprietary, secure
- BMS is control, not analysis
- Requires large commitment of facilities staff time
- But, still can have its place



On the other end of the technological spectrum we have **Building Management Systems** or BMS's. A BMS is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power, fire and security systems. Building Management Systems are most common on larger buildings. BMS systems are a critical component to managing energy demand. Improperly configured BMS systems are believed to account for 20% of building energy usage, or approximately 8% of total energy usage in the United States.

This is a screen shot of one type of BMS view showing what is going on in part of a system. Some BMSs can log the data but it takes a lot of memory and slows the system down so Facility staff often don't like doing it. Additionally, the BMS sensors are placed to allow it to monitor itself and its own performance. Having an independent check where you can actually control where the data is being collected and is more representative of what the collections are actually feeling – can be valuable. If you are a collection manager, curator, registrar, or conservator ultimately your job isn't to run the system – but to work with the facility staff who run the system to ensure that is performing to meet the needs of your collection. Again, remembering that this monitoring is a means to an end.

So, while the BMS can log and analyze data, and this might be necessary when addressing a specific problem, even if you have one, this won't be a good-long term solution for most of you.

Hardware: Dataloggers

- Electronic devices that measure T & RH for graphing and analysis on computer
- Most popular and practical

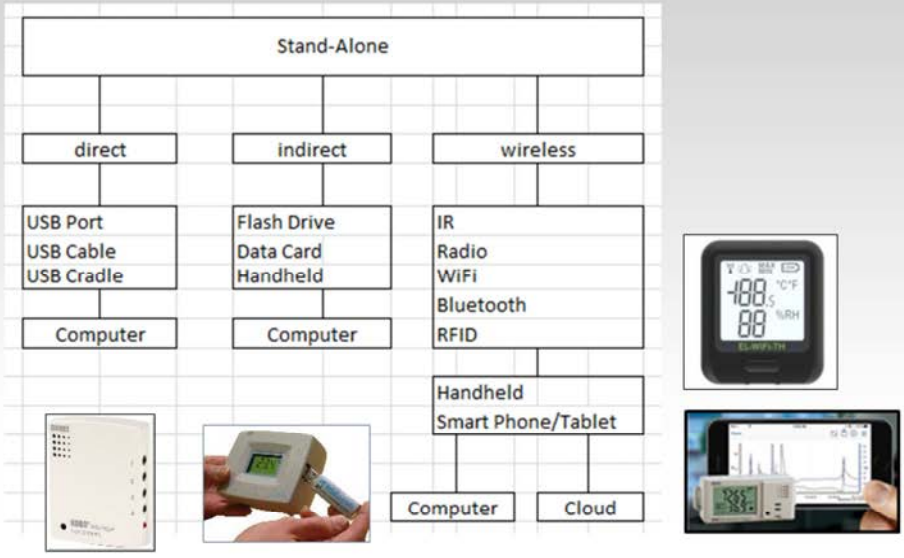
So that brings us to the monitor of choice these days in our field - the datalogger. Datalogger is a general name for a battery powered device with a sensor and microprocessor that will record information. For our purposes, at a minimum this includes temp and RH but as I mentioned earlier can also include other parameters such as light, occupancy, open/close, on/off.

I'm interested to see if why people might be looking to change their monitoring equipment. So here is Poll #3.
Poll Question #3 If you are looking to change your monitoring equipment why? (pick your top issue):

- It is too hard to set up
- Collecting data is too time consuming
- I can't access the information easily when I need it
- I have trouble understanding the information
- The unit isn't reliable due to quality or age
- I'm not sure the data is accurate

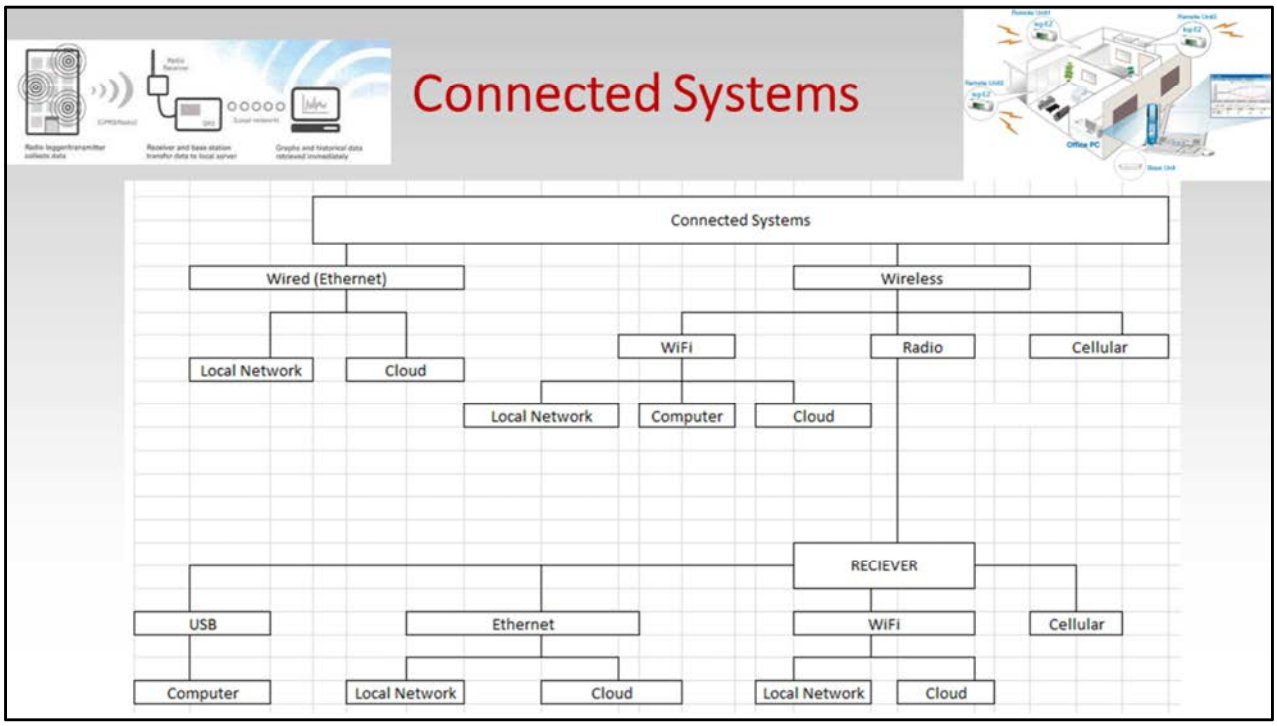
Now here is where is starts to get complicated. If you look at these loggers – there aren't any wires sticking out. They are, in fact, wireless at least while they are logging.

Standalone loggers



With standalone dataloggers each logger works independently and you have to download the data to view the results. There are different way in which you can download the data:

1. Directly via a USB connected port, cradle or cable
2. Indirectly using an intermediary device like a flash drive, SD card or handheld shuttle device
3. Wireless where the logger communicates to an intermediary device and then to the computer or cloud

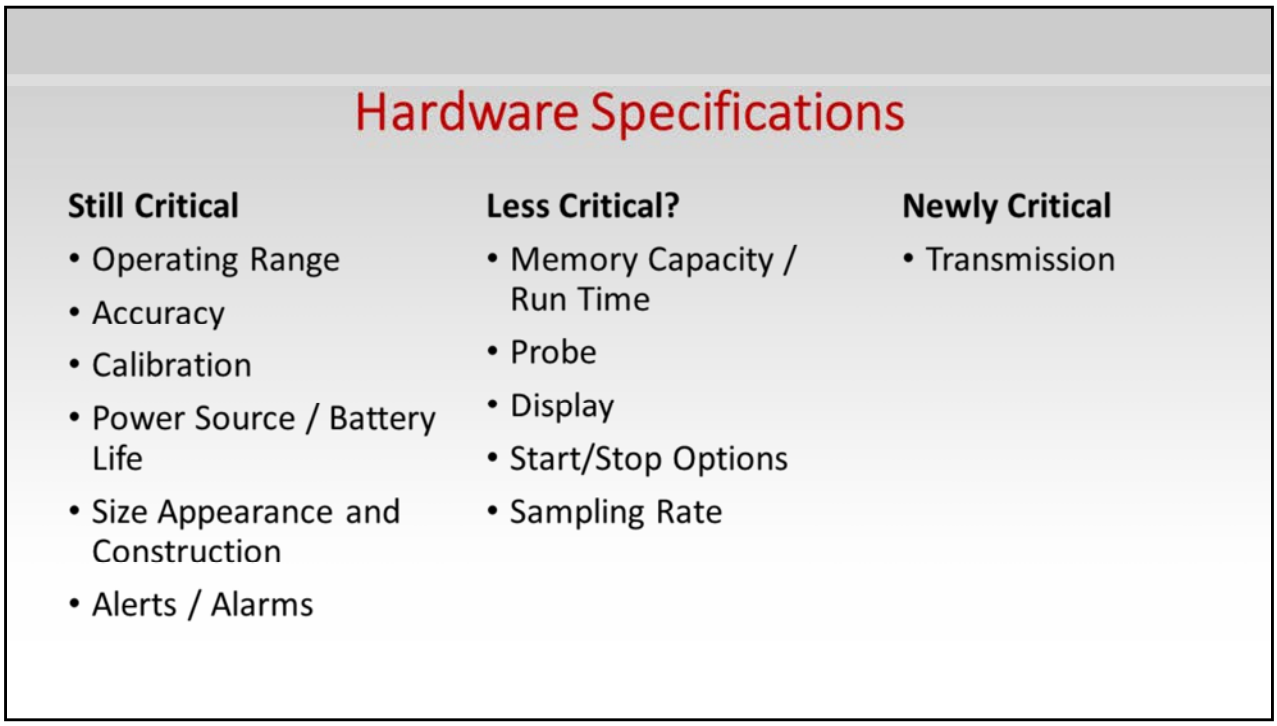


The opposite of a standalone logger is a connected system. Connected systems are often mislabeled as Wireless loggers but this is a misnomer in two ways.

1. Not all of these sensors are logging and storing the information. Some merely sense the information and then relay relaying it to the nearest collection point
2. These systems can be wireless or they can be hardwired into your Ethernet.

With connected systems we are talking about those that communicate with a network and, sometimes, with each other. They transmit the data in various ways (i.e. wifi, radio, cellular, wiring) and to various points (computer, network, cloud). And generally the communication is two-way.

Before I start talking about the different ways that data can be transmitted wirelessly I want to talk a bit about some logger features you should understand.



I don't want to spend a lot of time on specifications because it is discussed in Conserve-O-Gram 3/3 https://www.nps.gov/museum/publications/conserveogram/03-03.pdf
And if want a more detailed explanation of these parameters you can listen to the 2012 Connecting to Collections Online Community webinar that I gave on choosing a datalogger http://www.connectingtocollections.org/recording-community-webinar-choosing-the-datalogger-that-is-right-for-you/

But there are both hardware and software considerations that are important to consider when choosing a product. Some of these parameters are still important for connected systems or wireless loggers – namely those on the left of the slide. And the ones in the center are still worth understanding but may be less critical given the different technology. Newly critical is the issue of transmission – in the right hand column. I want to highlight a few of these parameters because even though the specs will continue to change, this information is really important in evaluating systems that are out now as well as those that will come out in the future.

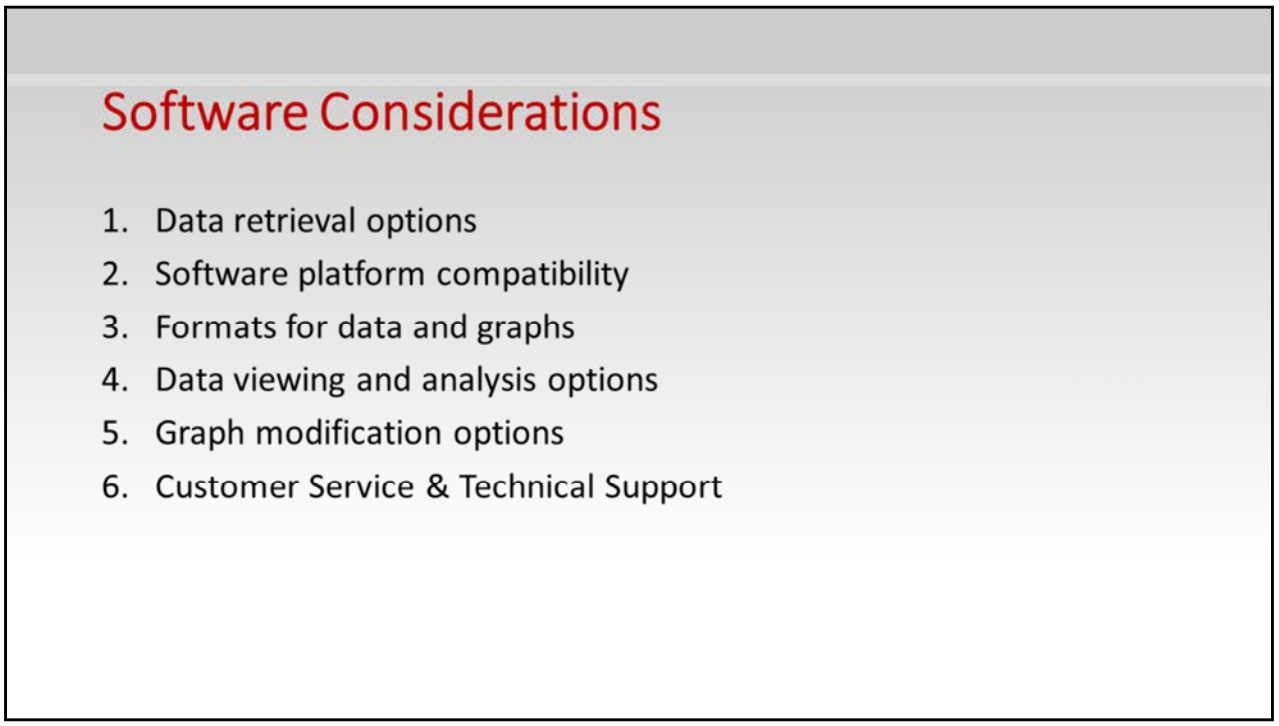
•Operating Range – this is the range of temperature and RH over which the logger will work. Generally most sensors function over a temperature range beyond what we expect to see in our collection environments but you have to sometimes pay close attention to the RH range. For instance the T&D log-EZ has an RH operating range of 15-90%. If you are monitoring in a case of archaeological metals or you are in the southwest where conditions are extremely dry – that might not go low enough for you. There are loggers that will work in freezers and outdoors but again, check your specs for details.

•Accuracy – You need to know that your data is accurate and some of these products are calibrated more carefully than others but the products that I'll be mentioning today are all acceptable for general museum purposes. And remember, if you aren't checking the accuracy of the equipment you are already using at least every couple of years, then it doesn't matter how accurate it was when you bought it - you can't have faith in the accuracy of your data. Some of the units considered have replaceable sensors which I really like, some can be self calibrated which is great if you have the time and capability to do this, but most need to be sent back to the manufacturer for calibration. This is an expense that you have to build into your maintenance budget. Several vendors have more than one model that measures Temp and RH and sometimes one will have increased accuracy. You have to determine whether that additional 1% accuracy in RH is worth extra money to you. N.B. generally temperature on digital probes will remain accurate. It is the RH that drifts generally towards higher readings.

•Power Source / Battery Life –Pay close attention to battery life to ensure that you will get enough power for your project. For wireless loggers you need the battery for both sampling and transmitting so it is even more crucial. Anything under one year at a reasonable sampling/transmission rate should be reconsidered. Remember that some connected systems transmit back to a receiver that will need a power source as remains permanently on - so that will influence its placement.

•Alarms – are an important function on wireless systems. The ability to get real time notification of problematic conditions can be great – or a burden. Systems now have various ways to indicate an alarm condition including on the LCD display, emails, texts, and audible alarms. If you don't have the staff or environmental systems to make changes based on these notifications they may not be valuable to you. If they aren't then you need to ask yourself whether you really need real-time data.

•Transmission – a new parameter to look for in wireless logger specifications is the transmission distance. When manufacturers give transmission distance they are generally talking "line of sight" so if they say 300 feet – that is in an open field or parking lot. Once you start putting walls, metal storage cabinets, and other things in the way that number diminishes fast. As I discuss the technology that the loggers use you'll see how this affects transmission. But for our uses you can always assume that any number listed in a spec sheet will be less than what is listed.



There is a long list of software considerations too. Consider both initial cost and the time and effort required to retrieve data and get it to proper analysis platform (software). Remember that software is often a separate expense. Capabilities of Software are critically important.

1. Data retrieval – how do you get the data off your logger:

- Cable
- Flash drive
- Portable download device
- Wireless

2. Are you using Mac or PC in your lab. If you are using mobile devices are the iOS or Android? This is critical to know to ensure that you can run the software or necessary apps to control the logger and view its output.

3. Formats for data and graphs – if you are a whiz with MS Excel then a stripped down software package may be fine for you. But if you like to be able to look at your data and print a graph without extra steps you should take a careful look at the proprietary software:

- Proprietary
- CSV
- Text
- html

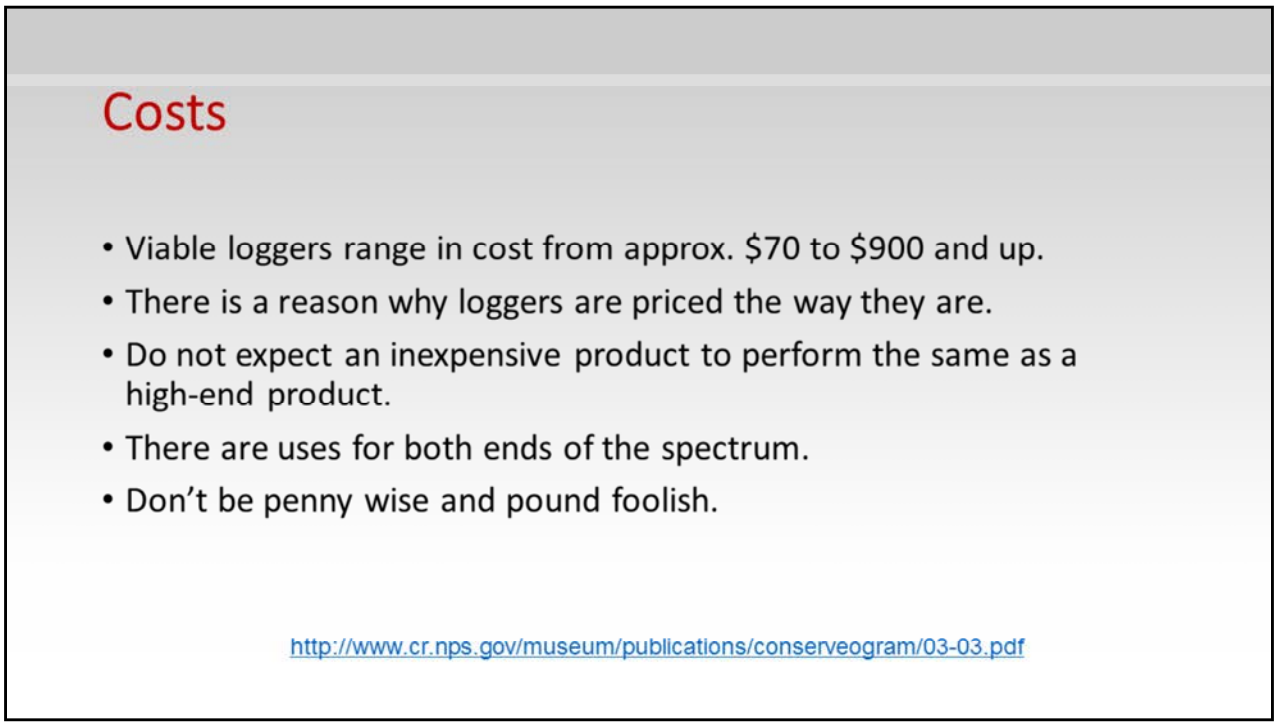
4. Data viewing and analysis options – The best software programs allow you to view a graph, as well as the raw data in table form and compile some basic statistics. It is nice to be able to see your target range or alarm setpoints on your graph. Fancier packages may allow for other features such

as overlaying graphs for comparison.

- Formats for raw data and graphs
- Raw data in table form
- Overlay graphs for comparison
- Statistics for data and data subsets
- Viewable data target ranges

5. Graph modification options – can you change the dates, scale or title on your graph? Not essential but may be a nice option

6. In this program I only included products from companies that understand our field's needs and generally offer good technical support. This is important especially with connected systems due to their greater complexity.



In 2012 cost was the primary factor in decision making. And here are a few things that I have found to be true about logger and system costs:

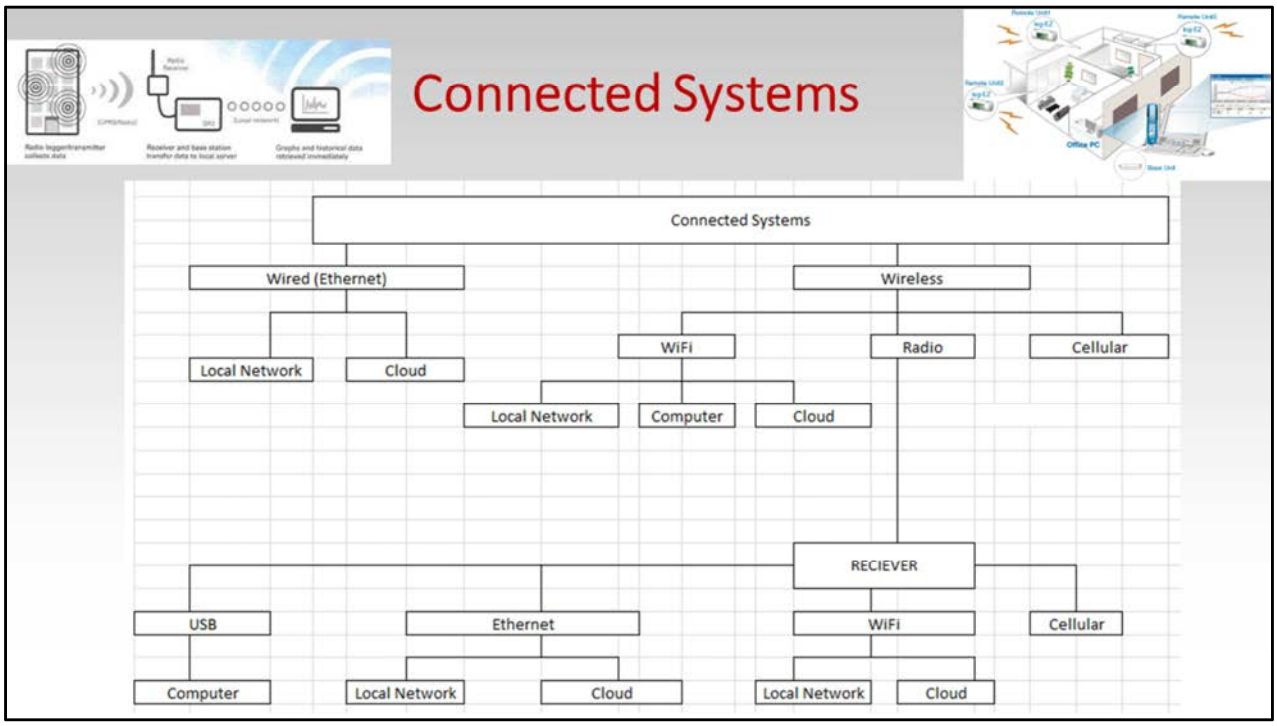
•Viable loggers range in cost from approx. $70 to $900. For connected systems some have a base price around $3,000 and then you add on sensors and repeaters from there.

•There is a reason why loggers are priced the way they are. The more bells and whistles the greater the price.

•Do not expect an inexpensive product to perform the same as a high-end product.

•There are uses for both ends of the spectrum.

•Don't be penny wise and pound foolish. There are ancillary costs to consider in terms of your network, time, workload, etc. You can factor those costs in to your budge make a justification for a more expensive product.



So now I want to focus on understanding wireless loggers and connected systems.

Terminology

- **Wireless** – "having no wires" but in the technology world describes any network where there is no physical connection between the sender and receiver.

- **Cloud** – shared computing resources on demand rather than using local servers or devices to handle applications. "THE cloud" = "the Internet"

We mentioned that our direct and indirect connection loggers don't count as wireless because you do need to physically touch those loggers to get your data. So for the purposes of today's webinar I'm going to be using **wireless** to talk about loggers that communicate without a physical connection.
http://www.webopedia.com/TERM/W/wireless.html

Next, let's discuss the word "**cloud**". Cloud means shared computing resources on demand rather than using local servers or devices to handle applications. "THE cloud" generally means Internet-based computing for storage and applications. Units like the PEM2 store information in the cloud but it isn't wireless. So you can see where we start to get some overlap. Four years ago when I did the last webinar on this topic none of the wireless loggers actually uploaded directly to the cloud. We knew it was coming and now it is here – this is the big change in the landscape. Several products now communicate directly with a cloud storage system but you have to look carefully at whether there are extra or ongoing costs with this service.
http://www.webopedia.com/TERM/C/cloud_computing.html

Terminology

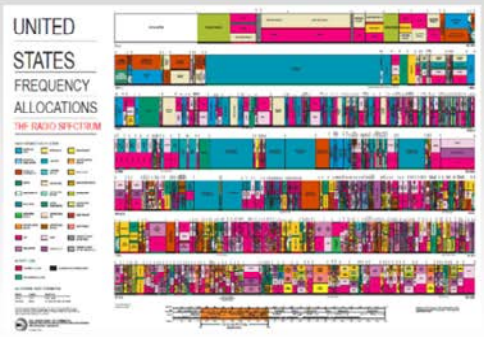
- **Wi-Fi** – a popular networking technology that uses radio waves to provide wireless high-speed network connections.

- **Network** – computers that are linked together into a system. A LAN or ***l****ocal-****a****rea* ***n****etwork* generally describes a system in a single building using *Ethernet*.

The next term we'll see on spec sheets is **Wi-Fi** – something that most of us can no longer live without! It is the most common wireless networking technology using uses radio waves to provide wireless network connections. We are going to talk about several wifi loggers today.
http://www.webopedia.com/TERM/W/Wi_Fi.html

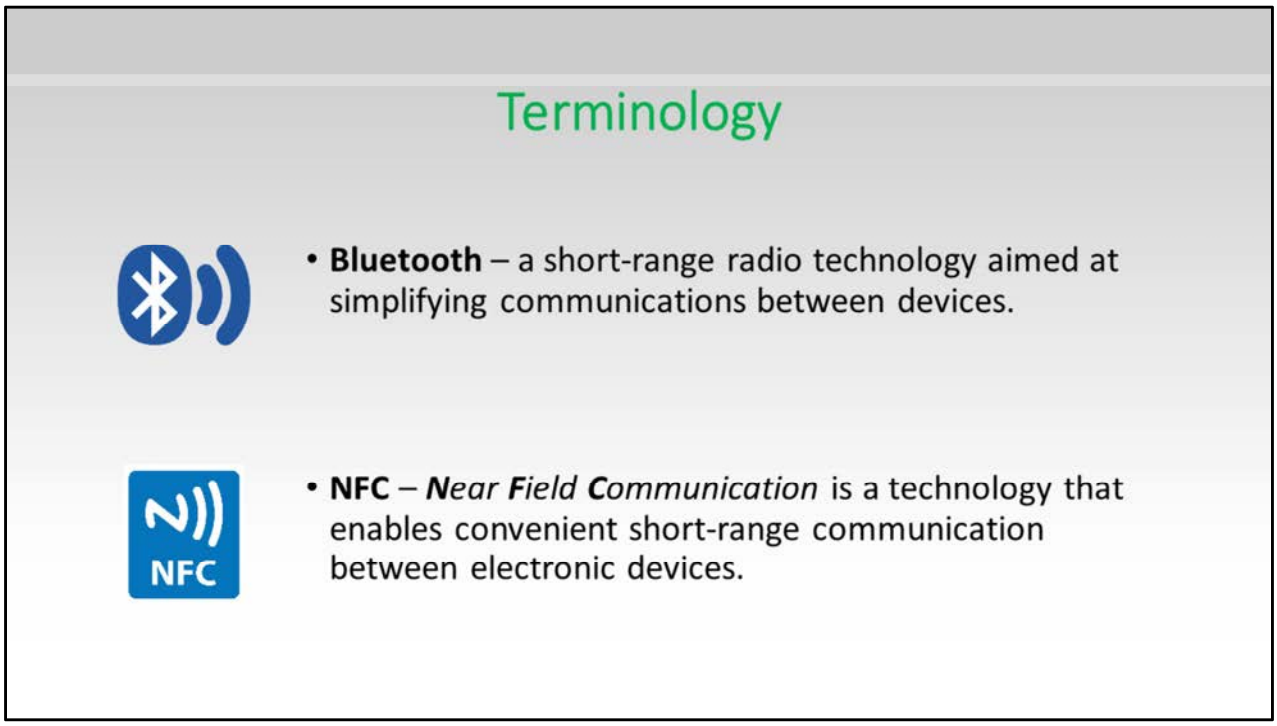
Networked - A network is a group of two or more computer systems linked together. There are many types of networks but the term that you'll see most frequently in this context is LAN – a local-area network which basically means that the computers are in some geographic proximity generally the same building. A network protocol defines the signals that computers on the network use to communicate. One of the most popular protocols for LANs is called *Ethernet.* Some of the systems available now are either wifi or Ethernet and some can do both.
http://www.webopedia.com/TERM/N/network.html
http://www.webopedia.com/TERM/E/Ethernet.html

Terminology



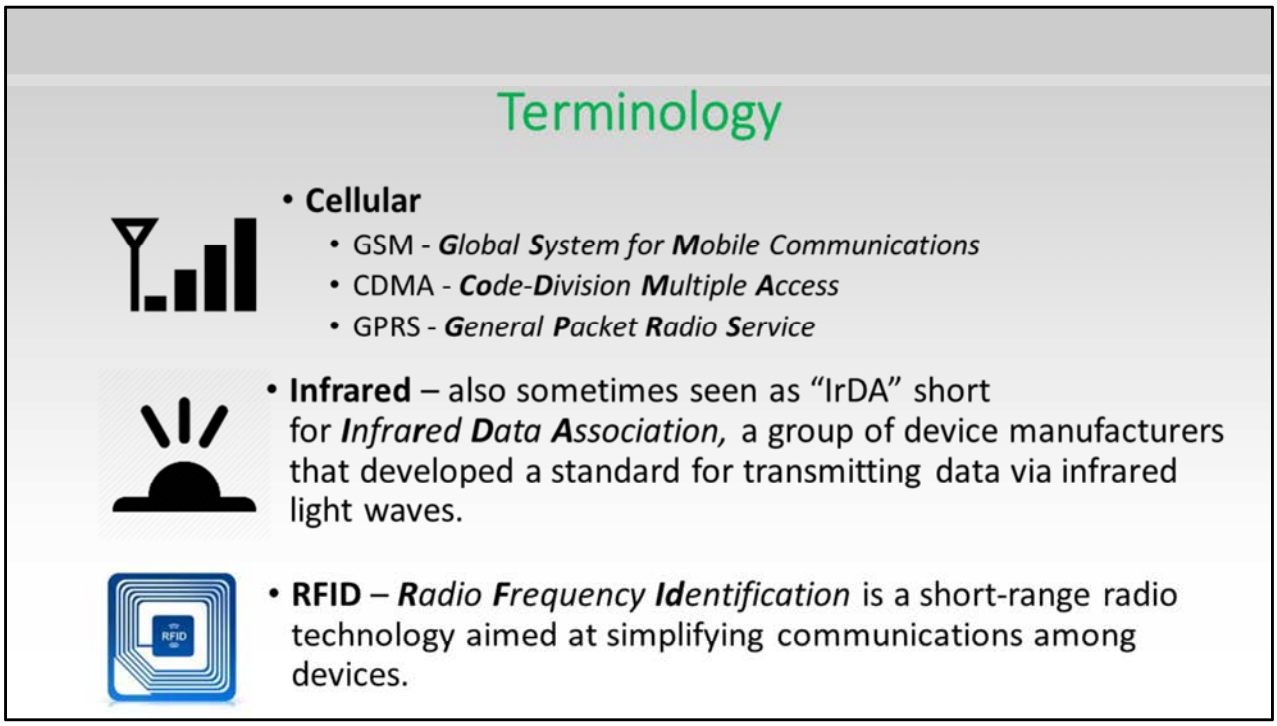
- **RF** – ***radio frequency***, is any frequency within the electromagnetic spectrum associated with radio wave propagation. When an RF current reaches an antenna, an electromagnetic field is created that can propagate through space.

RF – stands ***radio frequency***, RF is any frequency within the electromagnetic spectrum associated with radio wave propagation. Many wireless technologies are based on RF field propagation. This image here is a graphic of how radio frequencies are allocated in the US by the FCC. Some frequencies are open and others aren't. This is important to understand because the frequency on which an RF logger transmits determines the power of transmission (i.e. how far the signal goes in your building) and whether the system requires a site license or not.
http://www.webopedia.com/TERM/R/RF.html



Bluetooth – is a *short-range radio technology* aimed at simplifying communications between devices. There are different classes of Bluetooth transmission Class 1 devices like a laptop need more power but transmit longer distances. But the most common devices are Class 2 which require less power but transmit around 30 feet. In order for two devices to communicate using Bluetooth they must be "paired". We'll also be looking at some Bluetooth loggers today.
http://www.webopedia.com/TERM/B/bluetooth.html

Bluetooth is sometimes referred to as a type of Near Field Communication and they are similar but not the same. NFC has a transmission distance of only a few inches. But it doesn't require pairing and it uses little power. We won't be talking today about NFC loggers but it is something to keep in mind as you read spec sheets.
http://www.webopedia.com/TERM/N/Near_Field_Communication.html
http://nearfieldcommunication.org/bluetooth.html

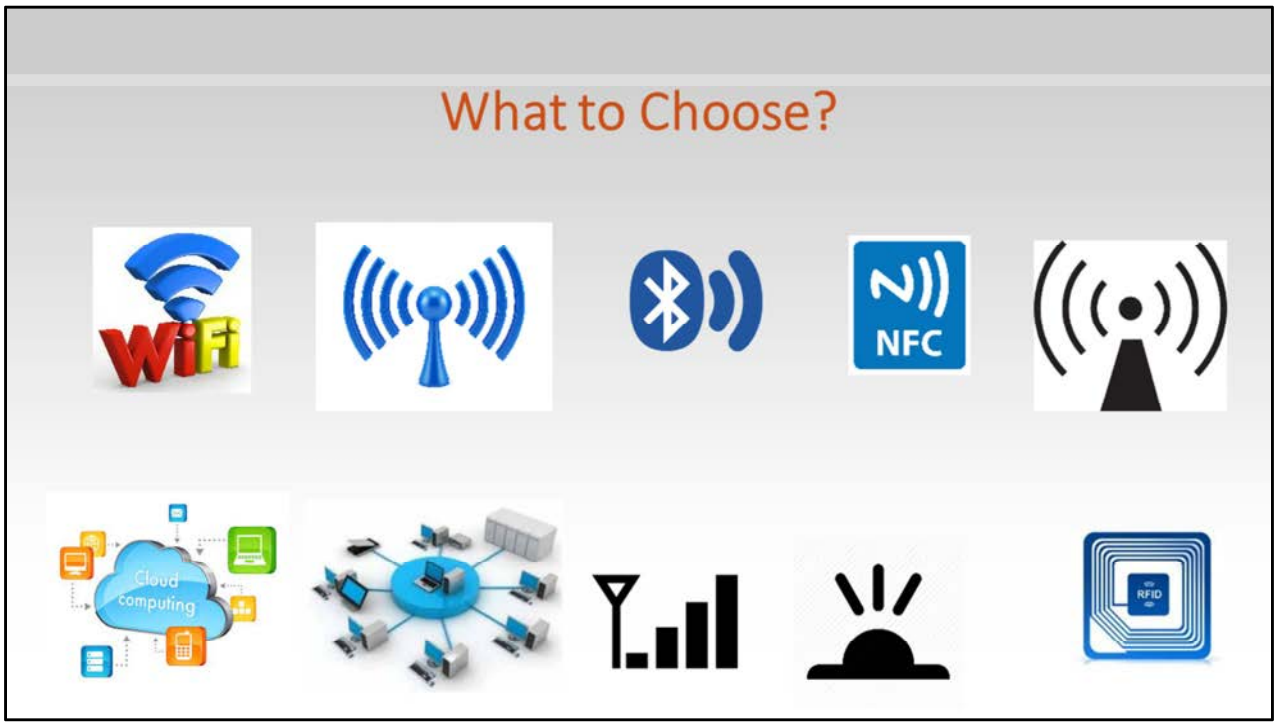


Cellular – There are different digital cellular technologies. You may see terms like GSM or others that I won't go into, but in the context of dataloggers refers to products that can transmit over a cellular phone network. These systems will require that you have a sim card and phone plan just like with a cellular phone. This quickly adds up to a major and ongoing expense, and these systems probably aren't the right fit for most institutions in our field with the range of other options we have.
http://www.webopedia.com/TERM/C/cellular.html
http://www.webopedia.com/TERM/G/GSM.html
http://www.webopedia.com/TERM/C/CDMA.html
http://www.webopedia.com/TERM/G/GPRS.html

Infrared – a term that most of us know about relating to the portion of the light spectrum is another way of referring to "IrDA" or a standard for transmitting data via infrared light waves. You need to have the sending and receiving units in close proximity (i.e. a foot or so) and direct line of sight to each other. There were a few loggers that used this technology and it was really the first way that logger companies tried to transmit wirelessly but it is outdated for our purposes and I'm not going to be discussing any units that function this way. But you still see them out there so I wanted to mention it so you'd understand how it works.
http://www.webopedia.com/TERM/I/IrDA.html

RFID - Short for ***r**adio **f**requency **id**entification*, is similar in theory to bar code identification. With

RFID, the electromagnetic or electrostatic coupling in the RF portion of the electromagnetic spectrum is used to transmit signals. RFID systems consist of an antenna and a transceiver, which reads the radio frequency and transfers the information to a processing device, and a transponder, or tag, which contains the integrated RF circuitry and information to be transmitted. This technology is best suited for monitoring things on the move (whether it is your dog, sweaters in a store or, in our field, art in transit). There is one logger from Monarch that uses this technology and I included links on the handout but unless you need the geolocating feature it isn't really a good choice for the kinds of basic monitoring we do most often. There is also a company eProvenance that provides a monitoring service for fine art or wine in transit using RFID trackers. So it is something to at least know about if the need arises.
http://www.webopedia.com/TERM/R/RFID.html



In the 16 years since I wrote the first National Park Service Conserve-O-Gram on evaluating dataloggers for museum monitoring there has been an explosion of new devices. Many of them are appropriate and accurate enough for most museum needs but there are differences in the products and the way their manufacturers describe them and people often find the choices overwhelming. This leads to one of my personal pet peeves. People will write in to various preservation listservs with a query like "I need to monitor my environment – what are people using that they are happy with?" And of course colleagues write back with answers like "We love our T&Ds" or "We have used Hobos with no trouble" etc. But this isn't the best way to ask or answer the question. The real trick is in matching your needs with the right product.

Before I start talking about the actual products I want to emphasize again that this is a selective list. These are ones that with one exception either I, my colleague Samantha or others whom we know have direct experience with. I have checked details with manufacturers and distributors for accuracy but remember that products and pricing changes. The handout that I made to accompanying this webinar lists the products by vendor and gives links to appropriate web pages for easy access to the technical specifications. But for now I'll talk about the loggers by connectivity type although within each grouping there is no particular order.

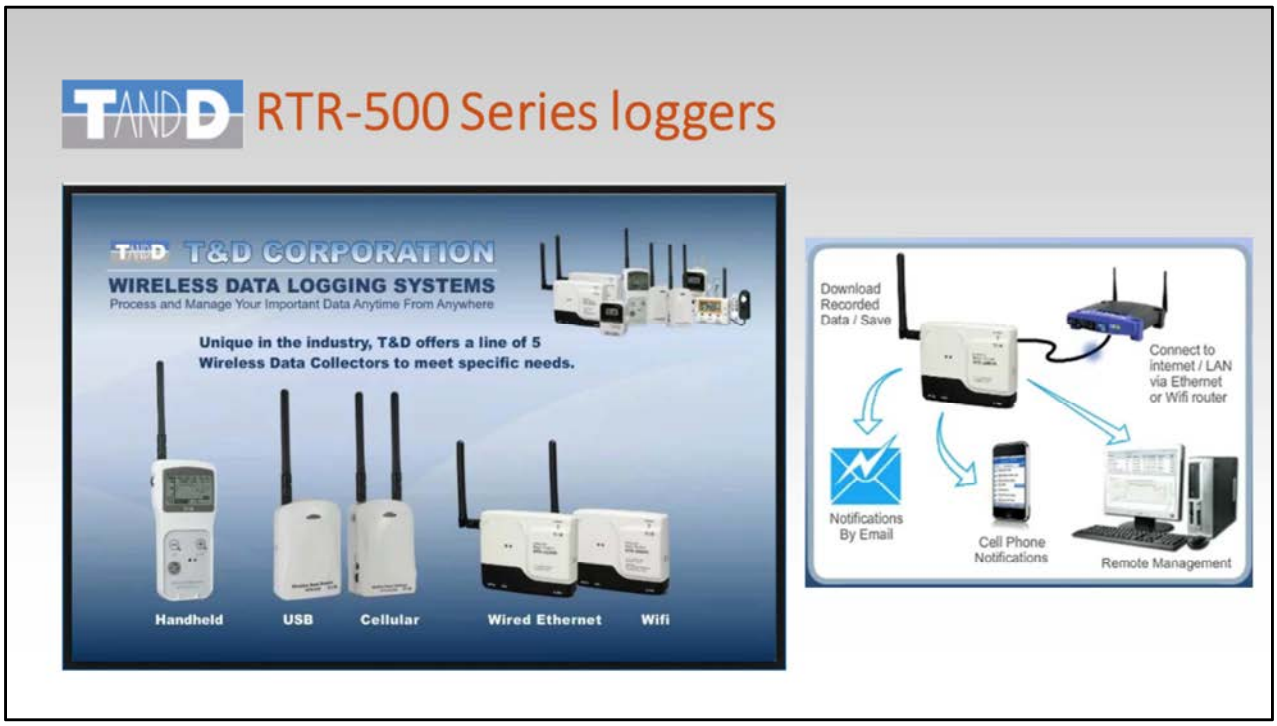
WiFi

- Takes advantage of existing IT infrastructure
- What is the level of WiFi encryption on your system? What level does the system support? Will your institution allow it?
- Potential for inference issues and can only place sensors where WiFi reaches (as opposed to radio)

Versus

Ethernet (wired)

- Most dependable communication, no physical impediment to sending signals (firewalls may interfere, need to work with IT) and no interference from other signals.
- Requires Ethernet port and sometimes power cord -physical wiring
- Less flexibility regarding sensor placement.
- Not appropriate for a very large number of monitoring points



The T&D Corporation RTR-500 series is a robust family of loggers that has by far the most connectivity options in a single product line. You can connect directly via a USB cable as a simple option, The handheld unit is great for mobile, drive-by or walk-in data collection. The units can be networked into your institution's LAN either using the wired Ethernet connector or the Wifi router depending on the nature of your network. And there is even a cellular option. So we've used basically all our terminology here! The system's good transmission rate and flexibility goes hand in hand with a higher cost but you can have your data either on your own network or use their free cloud storage. T&D only sells through distributors that have good tech support and their U.S. President is very familiar with our field and its needs. The RTR-574 is the only unit that logs UV and one of the more accurate lux loggers. The units have always been good quality and the software has improved greatly over time. This is a good option for a mid- to large institution with a complex building, varied needs and a good IT department. Pricing:

- RTR-503 temp and RH sensor - $249 RTR-507 higher accuracy sensor $319
- RTR-574 illuminance, UV, temp and humidity - $370
- Handheld $319
- Ethernet or Wifi Base station $259
- The software and the cloud storage is free

http://www.tandd.com/product/rtr500_series.html
http://cdn.tandd.co.jp/glb/product/outline-spec_rtr500-dataloggers-eng.pdf

T&D's #1 seller these days is the TR-7 Series. There are two versions of the logger – the wf works over WiFimeaning that you need to know your SSID and password to connect and the nf connects (with a wire) to your Ethernet. Again you see the confusion with the term wireless!

While you can store your data locally using the mobile apps, the unit is pre-programmed to interact with T&D's free, unlimited cloud storage. So these units have both varying networking and data options depending on your building and data sharing needs. There is no limit on the number of units you can have on the system. There are some nice hardware features like:

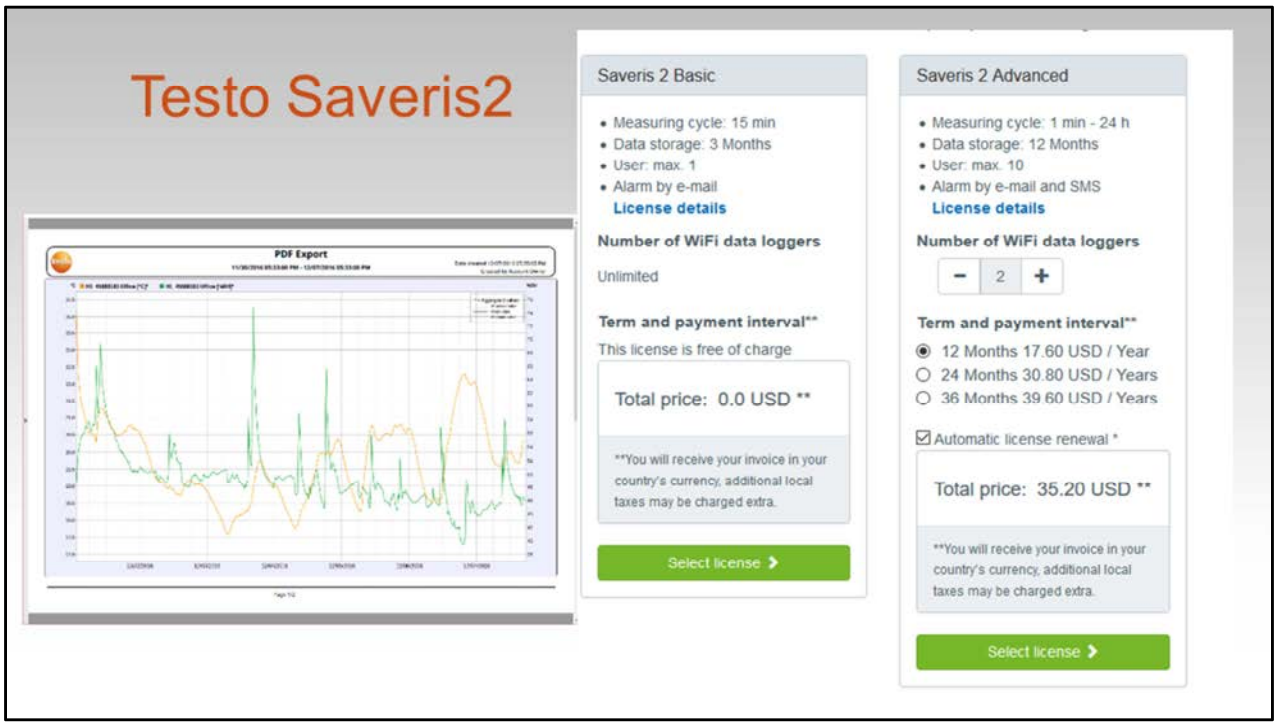
- 2 year battery life
- Internal memory
- Large LCD
- Replaceable sensors

The sensor cost has come down recently to $259 making it competitively priced especially when you add in the free storage. I think that this is a good option for institutions that don't have the need or capabilities for the 500 series. But you still must have a robust network in your building that reaches all the areas you want to monitor.

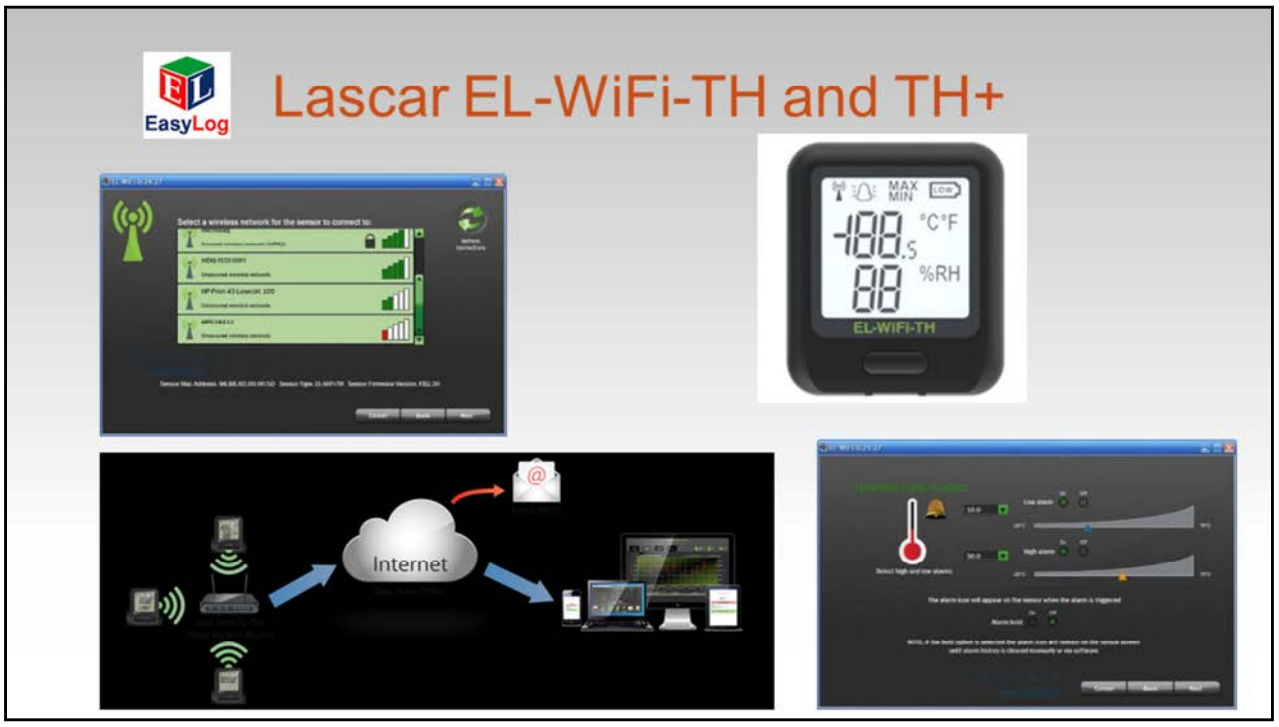
http://www.tandd.com/product/tr7wfnw_series.html
http://cdn.tandd.co.jp/glb/product/outline-spec_tr7wf_nw-eng.pdf

The Testo Saveris2 loggers is a newer one to the market. They exhibited at the last AIC meeting. I have been impressed with the ease of setup. There were a few things that I didn't find intuitive in their online software but a call to their support staff cleared things up quickly. The software allows you to group your units in different ways making it easy to manage data for large numbers of loggers. The reports look nice and the app worked well on both the iPad and Android devices. I set up the alert functions to send text messages and that worked smoothly. The loggers must be on a secure system so it won't work on an open Wi-Fi network. While Gaylord Archival sells the other standalone loggers made by Testo you have to buy the Saveris 2 directly from Testo. Their website for this is currently a bit cumbersome but use the request info button and you'll get a quick response. The advantage is that they are very responsive and they will do special orders like custom probes.

http://www.testo.us/Saveris2/index.jsp
http://www.testo.us/museums/index.jsp
http://www.testo.us/media/cumulus_objects/Testo_Museum_Brochure2_cf2.pdf
https://www.youtube.com/watch?v=99-GvPp_BAQ



The 2HI which is the temperature and humidity logger sells for $316 but in contrast to the T&D there are additional costs. You must register the units and the basic license is free but your data is stored online only for three months meaning that you must have a good plan for backing up and archiving your data. If you purchase the advanced license it is $17.60 per device per year, which can quickly add up for a mid-size institution. This will give you two years of data storage so long-term archiving of data is still an issue. I've found that many institutions often buy hardware on temporary budget lines linked with grants, exhibitions or construction and so they don't like to have ongoing costs that have to then be included in a departmental budget. If this is an issue for you – reach out to Testo US directly to discuss your needs. I liked the hardware. There are a few things that I'd like to see with the reporting software but their representatives seemed interested in feedback. It will be interesting to see how it does in our market with the higher ongoing costs.

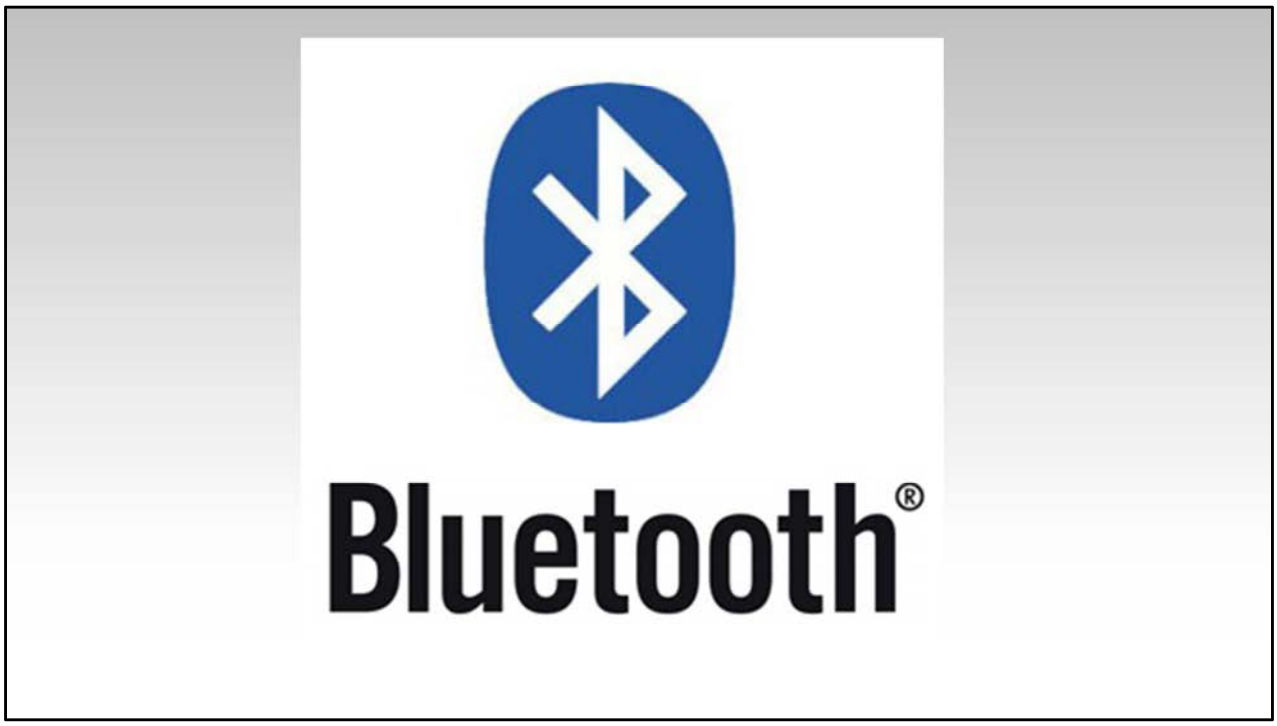


Lascar EL-WiFi

The Lascar EL-wifi was released just weeks before the 2012 webinar. I had trouble getting this logger set up in my institution in Israel – it just wasn't working well on my network even after extensive technical support. But eventually I received a new unit and the setup proceeded so sometimes you just need to persist! You can connect direct to a PC or use their cloud software Files Through the Air. It is free for 1-2 units but you don't have the full functionality that you get with the paid subscription service. For a lot of the things we want to do in terms of sharing our data with other departments or institutions for a facility report you really need the full subscription so keep it in mind if your administration balks at ongoing costs.

EL-Wifi-TH - https://www.lascarelectronics.com/easylog-data-logger-el-wifi-th/
EL-Wifi-TH+ - https://www.lascarelectronics.com/easylog-data-logger-el-wifi-thplus/
https://www.youtube.com/watch?v=CJZOO2Eo7o8

I like the dashboard view for a moderate number of loggers. Setup is easy and I think this a good option if you have either a small building and can throw the signal directly back to a receiving computer or if you have good Wi-Fi coverage in a larger building.



Bluetooth

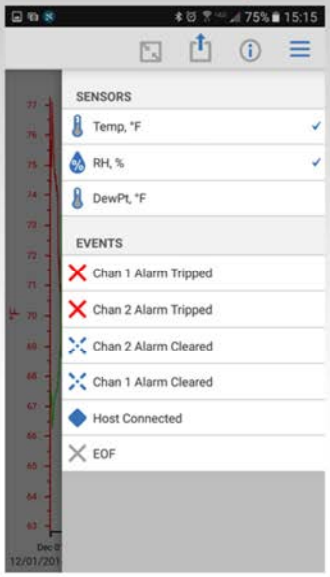
- Good option for enclosed spaces like vitrines or dioramas
- Requires some proximity
- Check whether data reaches the cloud or just to an app on a handheld device
- Ensure that pairing works with your platform

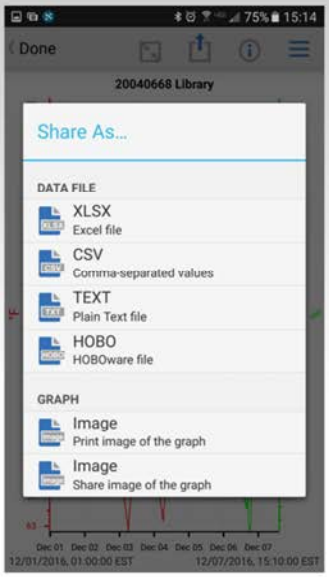
Onset Bluetooth Temp/RH MX1101

I have had a generally good experience with the Onset MX1101 Bluetooth logger. Initially when I first used this logger a few years ago I had some issues. First, my Android phone wasn't new enough for the app. Instead I used an iPad. The setup was very easy on the iOS platform. I had a few connectivity issues but a firmware update sorted that out and the Onset technical support was a big plus. Here the arrow in the image on the right points to one unit that I placed in a sealed vitrine (the bonnet isn't on yet) with one of Israel's Dead Sea Scrolls, that had very strict environmental and reporting parameters. I found that the battery life on the units was well under one year at that time but this problem which resulted from a power/transmission issue seems to have been corrected. At $135 the price is very reasonable.

Company website - http://www.onsetcomp.com/
Distributor – direct sales from Onset website or https://www.microdaq.com/
http://www.onsetcomp.com/products/data-loggers/mx1101
https://www.youtube.com/watch?v=_AegTkY0czg

Onset Bluetooth Temp/RH MX1101





The data from this logger does not go to the cloud, so someone needs to walk by the case to download the data but it is easy to export and share the data. Here are a couple of screen shots. My understanding is that Onset is working on developing cloud capability for the logger so stay tuned for that.

Lascar EL-BT-2 Bluetooth Wireless Temperature and Humidity Data Logger
I haven't had the chance to play with this new Bluetooth logger from Lascar but I like their other products. Each unit costs $160-$170 (depending on the distributor) so I am interested to see how it compares with the slightly cheaper Onset unit. The app is only available on Android devices.

http://www.dataloggerinc.com/products/ELBT2_Bluetooth_Wireless_Temperature_and_Humidity_Data_Logger/474/
http://www.dataloggerinc.com/datasheets/lascar/EL-BT-2-specs.pdf
https://www.youtube.com/watch?v=biJ7c-JKgs8&feature=youtu.be&list=PLPg4H1K--GN-MHkjiUCU0x1EHoHJaQD2R

T&D GR4 Series

- Bluetooth logger
- Phone or tablet app
- Expected early 2017

And I have been told that T&D has a Bluetooth logger that will be released in 2017.

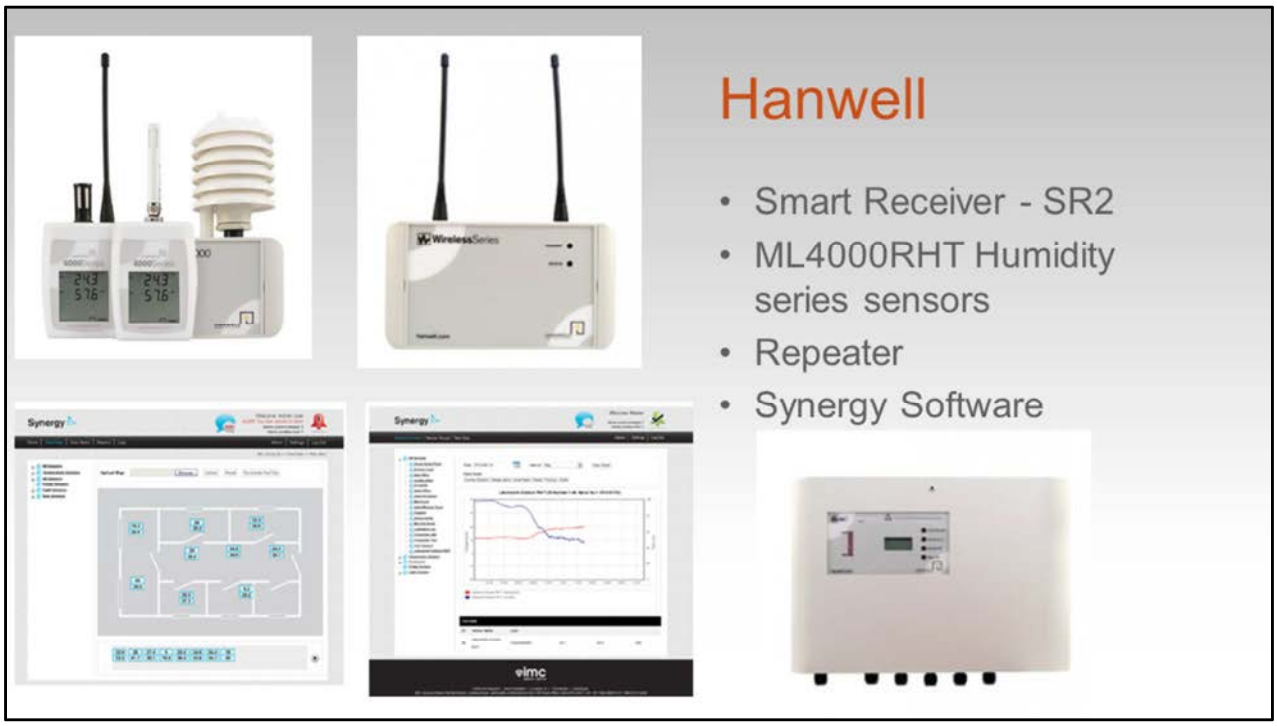
Radio - Frequency: How data is sent from logger/sensors to receivers

Frequency: 2.4 GHz (=2400 MHz)
- Generally set-up is simple, some options among least expensive of connected systems.
- Does not send signal as far as other radio frequency choices (manufactures state 50-90m)
- More potential interference from WiFi, microwaves and other short wave signal

Frequency: 900MHz
- Sends signal farther (manufacturers state 150-200m) than 2.4 GHz systems so you can cover same footprint with less units
- Less interference potential than 2.4GHz (but interference still possible, guard radios and other radio signal)

Frequency: 450MHz
- Unlike others this is a band that requires licensing
- Potentially much farther reach than other shorter frequencies and less interference

Receivers: What types of receiver? How data is collect and interfaces with user - can be Ethernet, WiFi Cellular, USB-PC



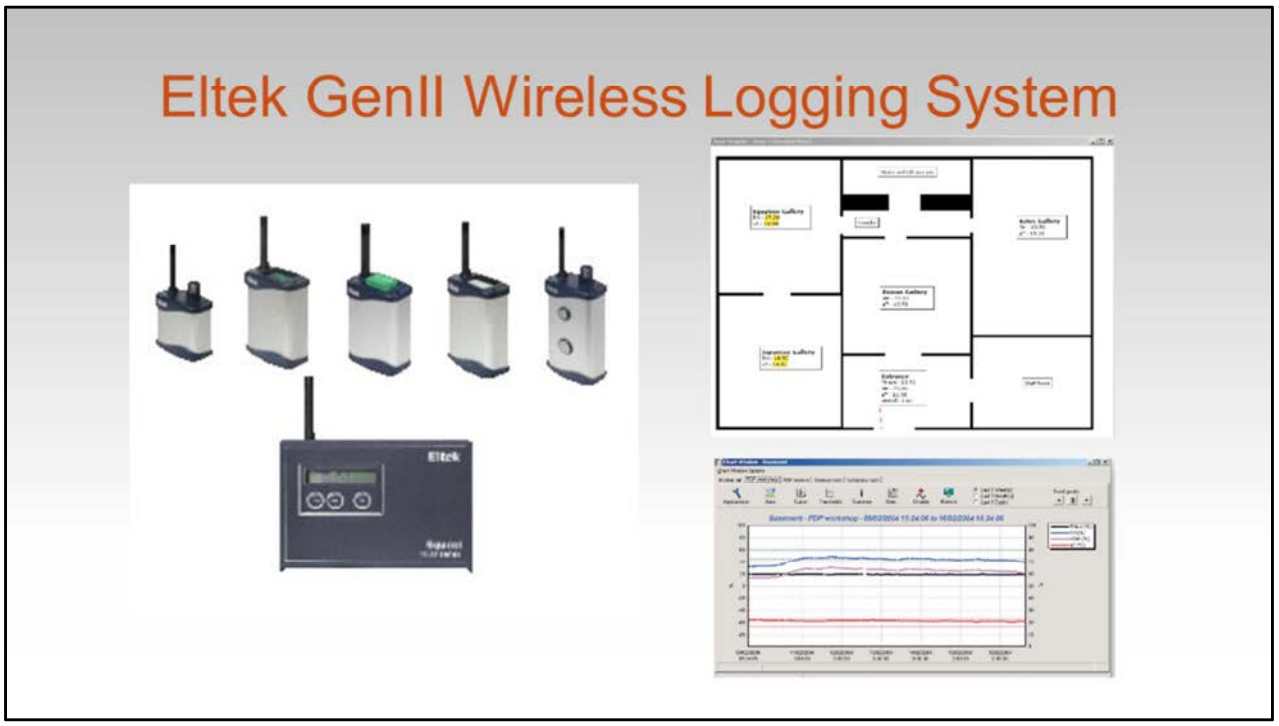
Hanwell

Before wireless systems became cheaper and more common, Hanwell basically had a lock on the market for a while with their radio telemetry system. Many institutions in the US and UK have installed the system but its main drawback was the need to beam the data from the sensors to a single PC based collection point which often required the use of numerous “repeater” units to extend the signal. Now, this system has good signal strength due to the transmission frequency but it requires a site-specific license. And the newer Smart Receiver2 wirelessly gathers the radio data from each transmitter in the building, saves it and if it is connected to your intuitions’ LAN passes the data on as requested to the server. PCs on the LAN network can view the live or historical data as needed. The Hanwell sensors tend to be physically larger that other loggers (something to consider if you wanted to put them inside a display) but they also have a USB option and they are robust with long battery lives. In addition to monitoring Temp and RH there are other compatible units to measure light, UV, dust accumulation, oxygen, carbon dioxide, etc. and more allowing you to beam all sorts of info to your desk!

The basic starter package includes the Smart Receiver - SR2 ($2,000 alone), Synergy Software, and FCC site license for ($3,000). Then on top of that you add the cost of the ML4000RHT Humidity series sensors at $650 each. If you need to boost the signal then you can add an additional receiver for Ethernet connection or if relying on RF, repeaters ($1,400) depending on which is the most efficient way to increase your signal area.

Hanwell is now a product of the IMC Group in the UK and there are a couple of products like a GPRS cellular version of the system and the smaller sensor called the RF bug that are only available in the UK. This is an established product so there is a long track record but they aren't that responsive to the needs of individual clients. Their US distributor understands the system well and works with the client to complete the installation.

Company website - http://www.the-imcgroup.com/data-loggers
Distributor - Cascade systems - http://www.cascadegroupinc.com/
ML4000RHT system
http://www.the-imcgroup.com/product/ml4000rht-humidity-series
http://www.the-imcgroup.com/images/Datasheets/ML4000RHT-Datasheet.pdf



The Eltek GenII Wireless Logging System is similar in some ways to the Hanwell system and both are widely used in the UK. Eltek entered the US market far later. The sensors transmit via radio frequency back to a single point receiver. You have to see the higher startup cost of a system like this (or the Hanwell) as the price you pay to be able to transmit your signal in the absence of a Wi-Fi or Ethernet system. CAS Dataloggers which is a distributor of several logger systems and can provide a lot of good information believes that even though this system is somewhat expensive to set up, it may be worth the price for larger institutions with a complex plan as the signal strength is considered fairly good. However, what is billed as a 3,200 line of sight transmission is more realistically around 650 feet in a museum. The base station which can connect to a PC or the internet is $1,800. The basic software is free but the more useful DARCA heritage software which is well designed is $1,000. There are two types of sensors one with a LCD at $468 and one without at $382. If repeaters are necessary to increase transmission distance they are $850 each.

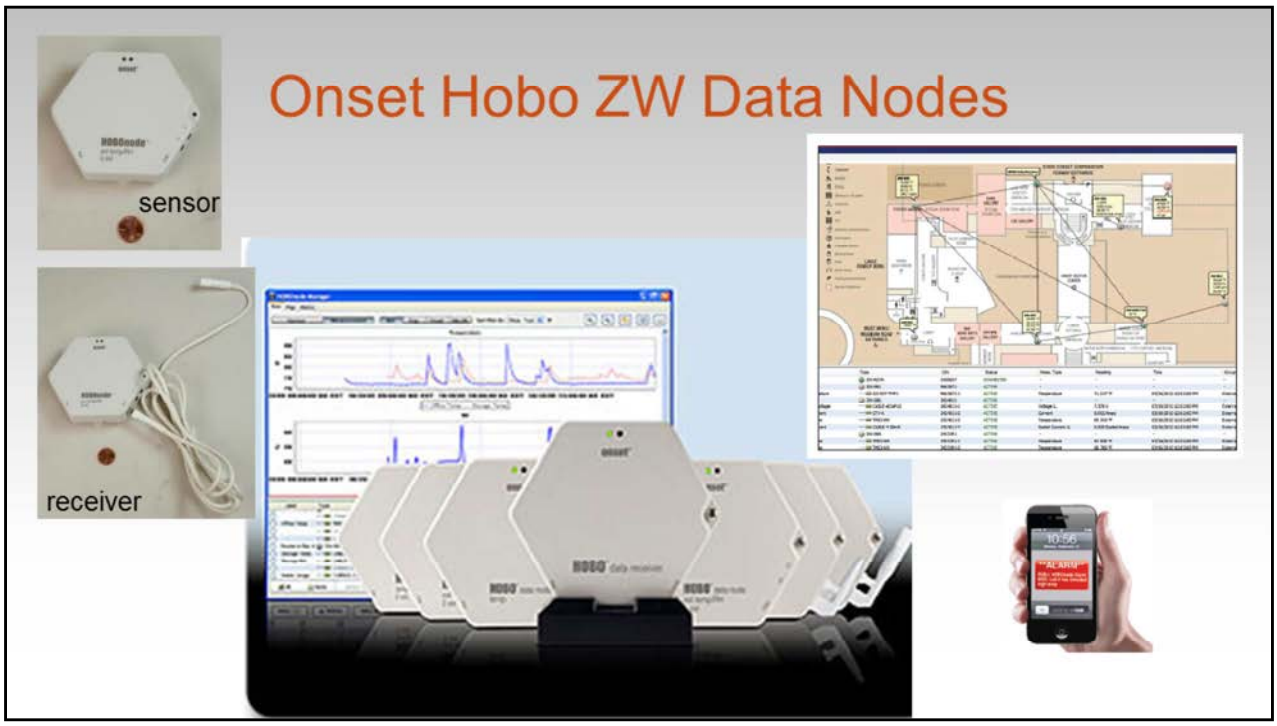
Company Website - http://www.eltekdataloggers.co.uk/

Distributor - http://www.dataloggerinc.com/manufacturers/Eltek/6/

http://www.dataloggerinc.com/manufacturers/Eltek/6/

http://www.dataloggerinc.com/datasheets/eltek-telemetry.pdf

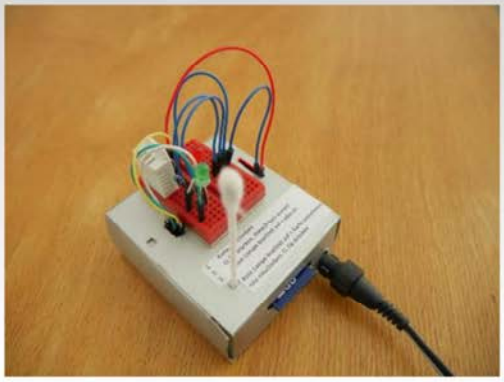
http://www.dataloggerinc.com/content/applications/environmental/702/wireless_environmental_monitoring_in_a_museum/



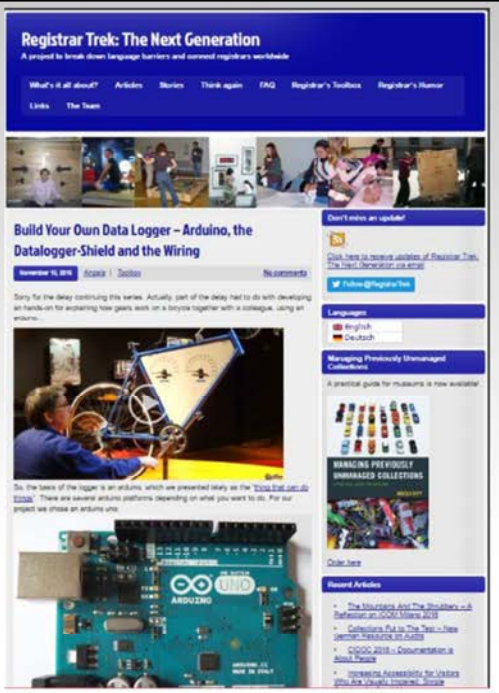
I am a fan of the Onset products as I feel they are generally good value for their money even when they have some flaws. And as a company Onset has broad familiarity with our profession and good support. The Onset ZW indoor wireless system also called the Data Nodes was one of the first plug and play system that I came across. This system works on your local network but if the base computer is connected to the internet then you can configure the software to email or text alarms or send or save data on your network. One issue with the nodes is that they need to be plugged in, which limits its placement. The battery on this unit is really for backup not for continued use and the sensor does some logging but is really meant to tide you over in the event of a power outage until your can communicate again with your collection point – so it isn't appropriate for an enclosed space like a vitrine. There are a number of institutions that are using this system successfully and so people sometimes mention it on the various listservs but this system has been superseded by others.

This wireless logger from T&D was an early entry into the wireless market. The small loggers communicated back to the wireless dongle that had to remain in your computer's USB port. It was easy to set up but there was little signal strength. That was somewhat compensated by the logger's ability to create a mesh network where each unit both sensed data and transmitted it on to your PC collection point. This means the more sensors you had on the system the more robust it would be. But the system didn't have any alert capabilities so the benefit of having the real-time data was somewhat lost. While this unit is still available and at $160 per sensor is inexpensive and the software free, you needed more of them to counter the short range. The battery only lasted about six months which was too short for my liking. I'd bypass this for one of T&D's other offerings.

DIY Options



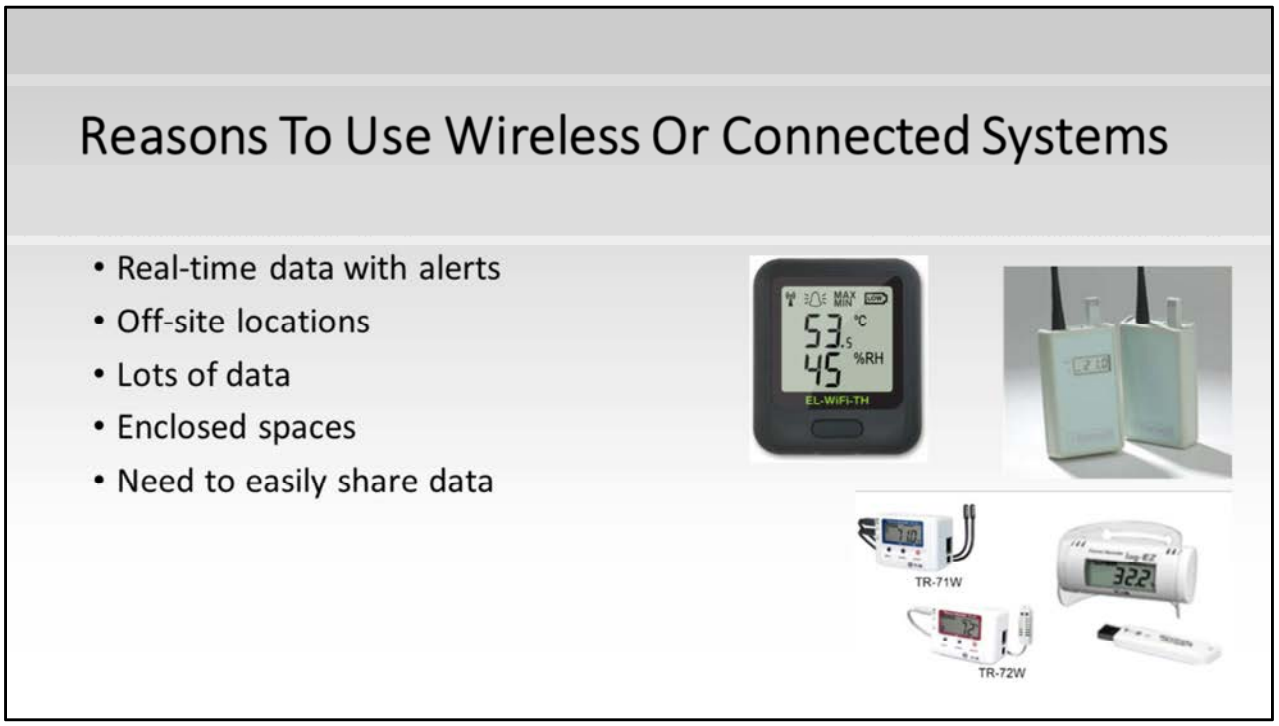
Registrar Trek Blog by Angela Kipp
http://world.museumsprojekte.de/



I want to point out that in addition to the many good products already out there and the new ones that will inevitably come, there are options to create your own logging system. I was fascinated by the series of posts by Registrar and blogger Angela Kipp on her experiements whipping up her own logger. But, unless you revel in STEM or your institution has unique needs - this isn't going to be the way to go.

Ultimately you can spend days or weeks researching options. But there are valid reasons why there are a more limited range of options that are appropriate for museum monitoring. In choosing a system you shouldn't forget some intangible things

- Service and technical support
- In house capabilities and expertise
- Your own time and sanity



Reasons for wireless
•Real-time data – It is super convenient to sit at your desk and click into your monitoring system to see what is going on. However, the main advantage to having real-time data is the ability to quickly learn of and respond to problematic conditions. If you are in an institution without climate control, you don't have the ability to make corrections and so the real-time knowledge, while cool, doesn't actually advance your collections care. *I'm going to emphasize this again. If you don't have an HVAC system, you have to have another compelling reason to use a wireless system*.
So those issues are similar to standalone dataloggers but how are wireless systems different?

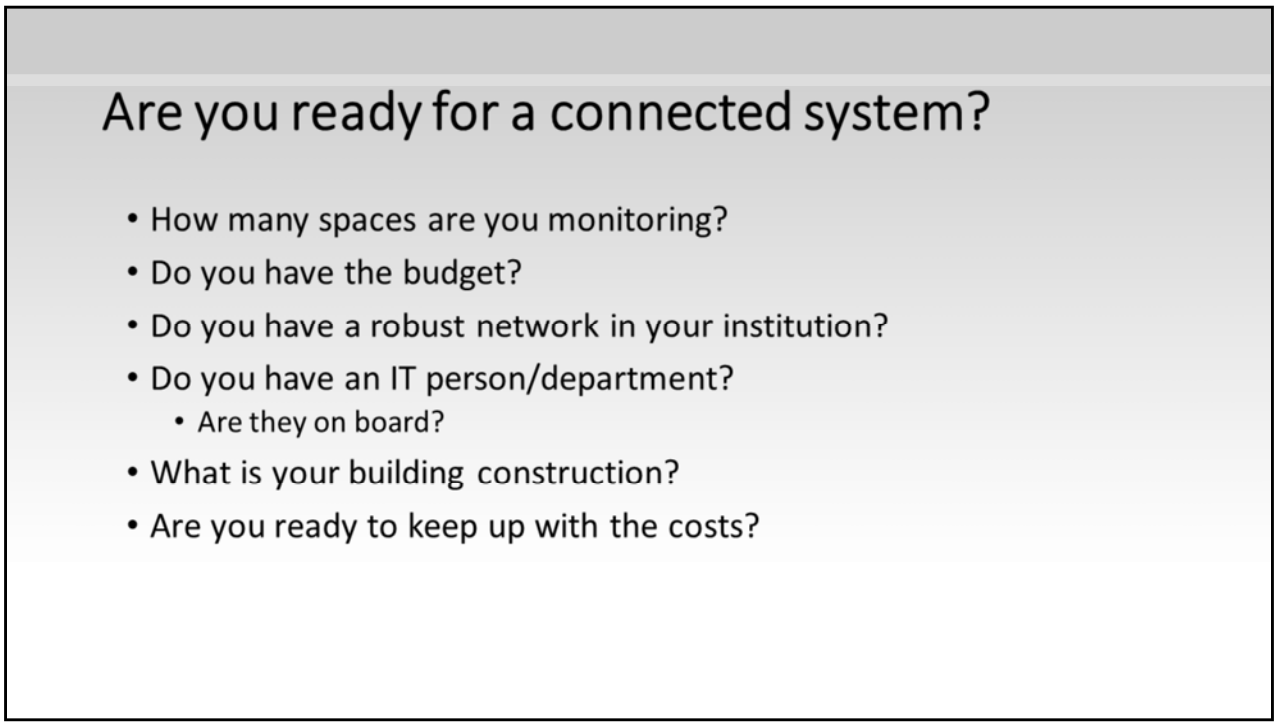
• Off-site locations – The need to monitor locations off of your main site would be a good rationale for wireless.

• Lots of data – wireless systems don't need a cable, flash drive or portable download device – they communicate without all those extras. By using a wireless system you eliminate the time spent going around your institution collecting the data. That can be hugely beneficial if you are in an institution that needs to monitor a lot of data points. And by a lot I mean more than 20.

• Enclosed spaces – one of those compelling reasons could be to monitor sealed microclimates. When I was at the American Museum of Natural History one of the cases I had to monitor was that of "copperman" a mineralized mummy of an ancient Chilean miner. The case was really well sealed with silica gel to keep the RH down as low as possible. A single wireless monitor would have been great to know when to open the case and recondition the gel. On a slightly larger scale you might have a special exhibit where the lender requests specific conditions and requires the case to be sealed after the courier leaves. Wireless transmission of data from the case would allow you to monitor the microclimate without going into the case.

Let's actually see what our audience thinks about these issues. Let's see polls #4 – 8.
Poll Question #4 - How many spaces or sensors are you currently monitoring?
- 0-3
- 4-10
- 10-20
- 21+

Poll Question #5 - Do you have the ability to control the environment in your space (i.e. do you have an HVAC system?)
- Yes
- No



Question #6 - What is your most important criterion in choosing a new environmental monitoring system?
- Price
- Accuracy
- Ease of use
- Software
- Connectivity

Question #7 - Do you have an IT department or at least one staff member with experience in wireless or networked technology?
- Yes
- No

Poll Question #8 - With whom do you share your data?
- Conservation
- Collections/Registration
- Facility Management
- Administration
- Nobody else is interested in my data?

Are you ready for a connected system?
- How complex to install?
- What system of communication is most appropriate for your structure?
- What type of IT infrastructure and support will be required?
- How many units will you need? Is there a limit to the units on the system?
- What types of loggers are available Temp/RH, UV/lux also? What are the features of the loggers?
- Are current conditions and alarms available at a glance?
- Can alarm notifications be sent and if so how?

Troubleshooting Wireless & Connected Systems

- Building construction
  - Metal
  - Concrete
  - Other wireless devices e.g. wireless phones
  - Other "noisy" devices e.g. fluorescent lights
- IT knowledge and support
- Device compatibility
- Firmware updates

Building construction - The key to wireless systems is testing them in your building because your ability to configure a system and transmit data successfully will depend greatly on your building's construction

- Place units away from metal building elements e.g. walls, floors and stairs
- Concrete will adversely affect transmission
- Keep wireless loggers far away from other wireless devices e.g. LAN's, cordless phones
- Keep wireless loggers away from noise-emitting sources e.g. electronic devices and fluorescent lamps

I highly recommend purchasing a single unit and testing it in your spaces. Speak to the manufacturer or distributor to explain that if it works you will buy more but don't buy a lot of any wireless or connected logger unless you check that it works in your building and on your network.

IT Support - These devices and systems are increasingly easy to plug and play. But since most of them require that they run over some type of network in your institution it is imperative that you have the support and cooperation of your IT department. If you don't have an IT department then you have to determine whether this is how you want to spend your time and energy because when they don't work they can become a real time suck. Some institutional firewall requirements will preclude the use of Wi-Fi loggers

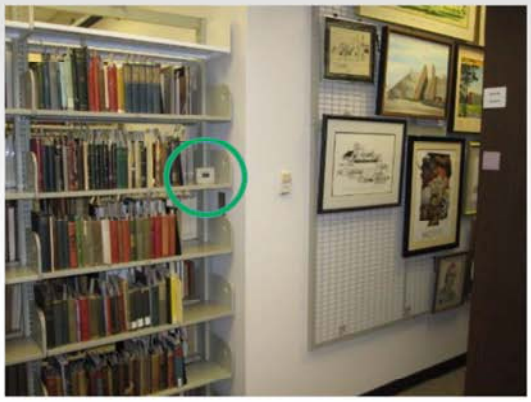
Device compatibility - I don't know about you all but with the numbers of devices I have in my family and the updates they need – it is exhausting. Consider whether you will have the time,

budget and interest in keeping your platforms and devices up to date and compatible.

Firmware updates – Firmware is software that is part of the read-only memory of a device. A number of the units I tested required firmware updates before I could begin or complete the logger setup and installation. If you purchase a logger from a vendor – you'll want to keep an eye out for emails or other notifications about firmware updates to ensure that your device continues to run properly. If you are having trouble checking the vendor website for firmware updates is a good idea as a first troubleshooting measure.
http://www.webopedia.com/TERM/F/firmware.html

Guidelines: Logger Locations & Coverage

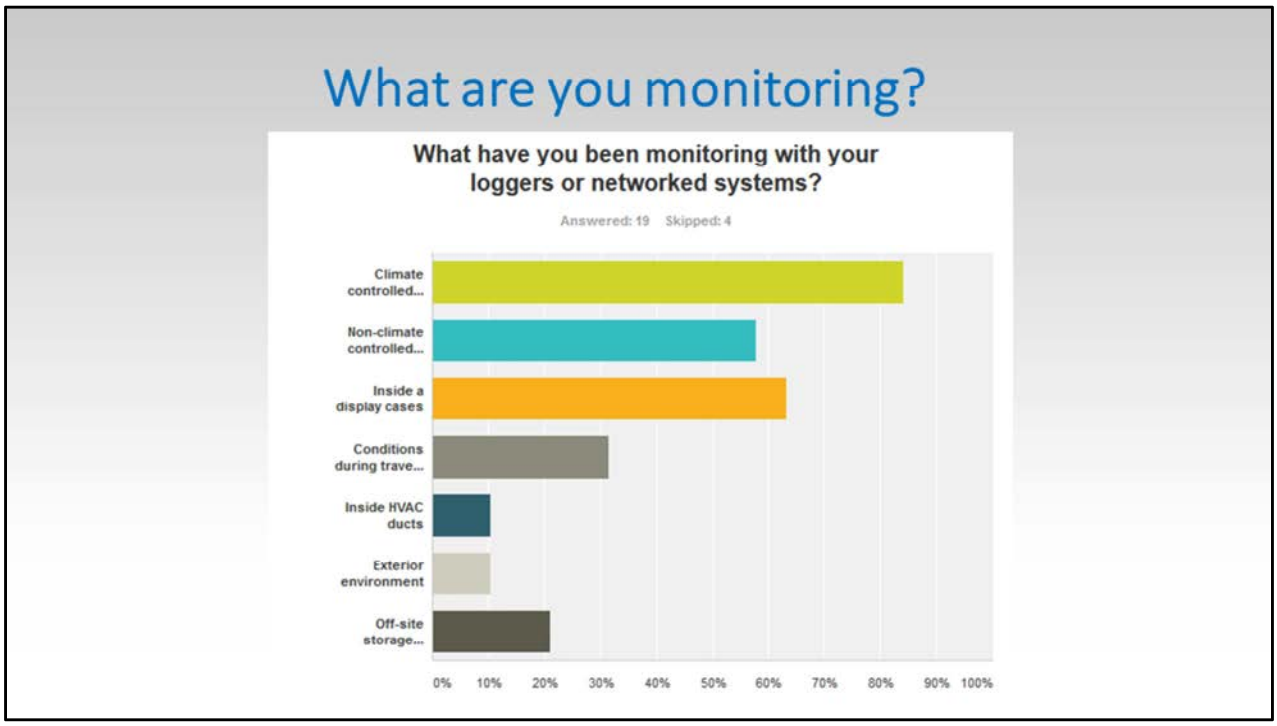
- No magical number of monitors/locations
- Monitor what YOU need to know
- Wherever there is reason to believe conditions may differ
  - Source of heat, cold, moisture



The number of loggers you need depends on your space(s), needs and, of course, budget.

- Are there preservation concerns?
- Collections/objects of significance?
- Are there microclimates?
- Do you have large spaces or multiple air handlers?
- Existing space or building issues?

Place your logger to get the data you need. Do you want your data to be representative of a space, near a particularly significant collection or to diagnose or confirm suspected poor conditions?



This data is from a pre-workshop survey that Samantha and I did. I'm interested to see how this small sample matches our audience today.
Let's have our final poll Poll Question #9 - What are you monitoring?

- Climate controlled areas
- Non-climate controlled areas
- Inside a display case
- Conditions during travel
- Inside HVAC ducts
- Exterior environment
- Off-site storage

J.P. Brown and William Rose in an excellent 1997 article available on CoOL (http://cool.conservation-us.org/byauth/brownjp/humidity1997.html#fn75) draw a distinction between:

- *confirmatory* monitoring (low sensor density, low data volume, permanently installed units, long term objective) aimed at ensuring that general, chronic problems of indoor climate are being controlled to the desired limits
- *investigative* monitoring (temporary installation, high sensor density, portable units, high data volume, short-term objective) to discover the source of a particular acute problem and generate appropriate solutions.

Confirmatory monitoring may detect a general problem (RH too high, or condensation on

windows), but it is often the case that additional investigative monitoring is needed to assign causes and generate sensible solutions. Confirmatory monitoring is not a substitute for a regular program of careful visual inspection. Understanding the difference in these types of monitoring will also factor into the decision of what kind of system will give you the data you need at the most reasonable price.

Guidelines: Logger Placement

- Amidst collections or in display
- 4-6 feet from floor
- Accessible for downloading
- Away from HVAC supply ducts

After you've decided on the room – figure out where you can comfortably place the unit so that it is:

- Accessible
- Not on floor or near ceiling
- Not under a duct or against a window or heater or in direct sunlight

Guidelines: Data Management

- Data should be examined regularly
  - Monthly
  - Seasonal
  - Anomalies or emergencies
- Data should be easily accessible
  - Backup to network/dedicated folder

No matter where your data is initially going – whether to a phone, tablet, PC or cloud, you should be examining it regularly to ensure it is functioning properly, that your spaces are performing as you anticipate and you are sharing it as needed and you must be backing it up.

Remember, the right system is one that provides the data that you need to answer the questions and address the issues you have. That might be a few PEM2s or it might be a system that uses standalone loggers and some form of wireless or connected system. I hope that even after new products hit the market that the framework for understanding the technology of these products and how they can be used in our institutions will remain useful.

Don't forget that there is a lot of useful information on managing your environment on the connectingtocollections.org resources pages.
http://www.connectingtocollections.org/resources/

GENERAL ENVIRONMENTAL MONITORING & MANAGEMENT INFORMATION
Wireless Environmental Monitoring: Is it right for you? C2CC 2016 Webinar
Choosing the Datalogger That Is Right for You C2C 2012 Webinar
Wireless Dataloggers C2C 2012 Webinar
Wireless Datalogger C2C 2012 Webinar Handout
Conserve-O-Gram 3/3 Comparing Temperature and Relative Humidity Dataloggers for Museum Monitoring National Park Service
Environmental Guidelines for Museums Canadian Conservation Institute
Environmental Overview Image Permanence Institute
Monitoring Temperature and Relative Humidity NEDCC
Managing the Library and Archive Environment The British Library National Preservation Office
Environmental Guidelines (AIC Wiki) Summary and History of Environmental Guidelines and recommendations for cultural institutions.

Rachael Perkins Arenstein is a founding partner in A.M. Art Conservation, LLC a NY-based private practice with specializations in object conservation and preventive care. She is the co-author of the National Park Service Conserve-O-Gram on Dataloggers for Museum Monitoring and has extensive experience presenting workshops and webinars on the topic of environmental monitoring. She has been responsible for implementing or maintaining environmental monitoring programs at the Bible Lands Museum, Smithsonian National Museum of the American Indian, the Peabody Museum of Archaeology and Ethnology, the American Museum of Natural History, and institutional and private clients both nationally and internationally. Rachael's degree in art conservation is from the University of London. She is Professional Associate in the American Institute for Conservation (AIC) and active in several professional organizations including positions as the e-Editor for the AIC and the Chair of the Integrated Pest Management Working Group.