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Today, as New Mexico celebrates 4/20 early, seems an appropriate time to talk about bhang... or rather, the bhangmeter.

The name of the bhangmeter seems to have been a joke by its designer and Nobel laureate Frederick Reines, although I must confess that I have never totally gotten it (perhaps I simply haven't been high enough). In any case, the bhangmeter is one of the earliest instruments designed for the detection of a nuclear detonation. In short, a bhangmeter is a photosensor with accompanying discrimination circuits (or today digital signal processing) that identify the "double flash" optical and heat radiation pattern which is characteristic of a nuclear detonation.

The double flash originates from the extreme nature of the period immediately after a nuclear detonation: the detonation creates an immense amount of heat and light, but very quickly the ionized shockwave emerging from the explosion actually blocks much of the light output. As the shockwave expands and loses energy, the light can escape again. The first pulse is only perhaps a millisecond long and has very sharp edges, while the second pulse appears more slowly and as much as a second or so later (depending on weapon type, conditions, etc).

The immensely bright light of a nuclear detonation, accompanied by this double flash intensity pattern, is fairly unique and has been widely for remote sensing for nuclear weapons. Today this is mostly done by GPS and other military satellites using modern optical imaging sensors, and the same satellites observe for other indications of nuclear detonation such as an X-ray pulse to confirm [1]. The bhangmeter itself, though, dates back to 1948 and always showed potential for large-area, automated monitoring.

The United States first effort at large-scale automated nuclear detonation monitoring was entrusted to the Western Union company, at the time the nation's largest digital communications operator. By 1962, Western Union had completed build-out of the uncreatively named Bomb Alarm System (BAS). BAS covered 99 locations which were thought to be likely targets for nuclear attack, and was continuously monitored (including state of health and remote testing) from six master control stations. It operated until the late '60s, when improved space technology began to obsolete such ground-based systems.

Let's spend some time to look at the detailed design of the BAS, because it has some interesting properties.

At each target site, three sensors are placed in a circle (at roughly 120 degrees apart) of eleven miles radius. This distance was chosen so that the expected sensitivity of the sensors in poor weather would result in a detonation at the center of the circle triggering all three, and because it allowed ample time for a sensor to finish transmitting its alarm before it was destroyed by shockwave-driven debris. If a nuclear weapon were to detonate off center, it may destroy one station but the other two should complete transmission of the alarm. This even allowed a very basic form of triangulation.

The sensors were white aluminum cylinders mostly mounted to the top of telephone poles, although some were on building roofs. On casual observation they might have been mistaken for common pole-top transformers except that each had a small cylindrical Fresnel lens sticking out of the top, looking not unlike a maritime obstruction light. The Fresnel lens focused light from any direction towards a triangular assembly of three small photocells. A perforated metal screen between the lens and the photocells served both to attenuate light (since the expected brightness of a nuclear detonation was extremely high) and as a mounting point for a set of xenon flash bulbs that could be activated remotely as a self-test mechanism.

In the weatherproof metal canister below the lens was a substantial set of analog electronics which amplified the signal from the photocells and then checked for a bright pulse with a rise time of less than 30ms, a brightness roughly equivalent to that of the sun, and a decay to half brightness within 30ms. A second pulse must reach the same brightness within one second and decay within one second.

Should such a double flash be detected, the sensor interrupted the 1100Hz “heartbeat” tone modulated onto its power supply and instead emitted 920Hz for one second followed by 720Hz for one second. These power supply lines, at 30vdc (give or take the superimposed audio frequency tone), could run for up to 20 miles until reaching a signal generating station (SGS).

The SGS was a substantial equipment cabinet installed indoors that provided the power supply to the sensor and, perhaps more importantly, monitored the tone provided by the sensor. The SGS itself is very interesting, and seems to have been well ahead of its time in terms of network design principles.

Long series of SGS could be connected together in a loop of telegraph lines. Each SGS, when receiving a message on its inbound line, decoded and re-encoded it to transmit on its outbound line. In this way the series of SGS functioned as a ring network with digital regeneration at each SGS, allowing for very long distances. This was quite necessary as the SGS rings each spanned multiple states, starting and ending at one of the three master control stations. Further, SGS performed basic collision avoidance by waiting for inbound messages to complete before sending outbound messages, allowing the ring network to appropriately queue up messages during busy periods.

During normal operation, the master control station transmitted into the ring a four-character “poll” command, which seems to have been BBBG. This is based on a telegraph tape shown in a testing document, it is not clear if this was always the signal used, but BBBG does have an interesting pattern property in Baudot that suggests it may have been used as a polling message as a way of testing timing consistency in the SGS. An SGS failing to maintain its baudot clock would have difficulty differentiating “B” and “G” and so would fail to respond to polls and thus appear to be offline.

In response to the poll, each station forwarded on the poll message and checked the tone coming from its attached sensor. If the normal heartbeat or “green” tone was detected, it sent a “green” status report. For example, “JGBW,” where the first three characters are an identifier for the SGS. Should it fail to detect a tone, it could respond with a trouble or “yellow” status, although I don’t have an example of that message.

Since each station sending its status would tie up the line, stations further down would have to wait to report their status. The way this queuing worked out, a noticeable amount of time after initiating the poll (around ten seconds by my very rough estimation) the master control station would receive its own poll command back, followed by green or yellow status messages from each SGS in the loop, in order. This process, repeated every couple of minutes, was the routine monitoring procedure.

Any SGS which failed to receive a poll command for 2.5 minutes would preemptively send a status message. This might seem odd at first, but it was a very useful design feature as it could be used to locate breaks in the loop. A damaged telegraph line would result in no responses except for 2.5 minute status messages from all of the SGS located *after* the break. This localized the break to one section of the loop, a vital requirement for a system where the total loop length could be over a thousand miles.

Should a sensor emit the 920Hz and 720Hz pattern, the attached SGS would wait for the inbound line to be idle and then transmit a “red” message. For example, “JGBCY,” where “JG” is a station ID, “B” is an indicator of approximate yield (this appears to have been a later enhancement to the system and I am not sure of how it is communicated from sensor to SGS), “C” indicates an alarm and “Y” is an optional terminator. The terminator does not seem to be present on polling responses, perhaps since they are typically immediately followed by additional responses.

The SGS “prioritizes” a red message in that as soon as an inbound message ends it will transmit the red message, even if there is another inbound message immediately following. Such de-prioritized messages will be queued to be sent after the red alert. For redundancy, a second red message is transmitted a bit later after the loop has cleared.

In the master control center, a computer sends poll messages and tracks responses in order to make sure that all SGS are responsive. Should any red message be received polling immediately stops and the computer begins recording the specific SGS that have sent alarms based on their ID letters. At the same time, the computer begins to read out the in-memory list of alarming stations and transmit it on to display stations. Following this alarm process, the computer automatically polls again and reports any “yellow” statuses to the display stations. This presumably added further useful information on the location and intensity of the detonation, since any new “yellow” statuses probably indicate sensors destroyed by the blast. Finally, the computer resets to the normal polling process.

When desired, an operator at a master control station can trigger the transmission of a test command to a specific SGS or the entire loop. When receiving this command, the SGS triggers the xenon flash bulbs in the sensor. This should cause a blast detection and the resulting red message, which is printed at the master control center for operator confirmation. This represents a remarkably well-thought-out complete end-to-end test capability, in good form for Western Union which at the time seemed to have a cultural emphasis on complete remote testing (as opposed to AT&T which tended to focus more on redundant fault detection systems in every piece of equipment).

To architect the network, the nation was first split roughly in half to form two regions. In each region, three master control centers operated various SGS loops.

Each target area had three sensors, and the SGS corresponding to each of the three sensors was on a loop connected to a different one of the three master control centers. This provided double redundancy of the MCCs, making the system durable to destruction of an MCC as well as destruction of a sensor (or really, destruction of up to two of either).

In each display center, a computer system decoded the received messages and lit up appropriate green, yellow, or red lights corresponding to each sensor. The green and yellow lights were mounted in a list of all sensors, but the red lights were placed behind a translucent map, providing an at-a-glance view of the receiving end of nuclear war.

In the ’60s, testing of nuclear defense systems was not as theoretical as it is today. While laboratory testing was performed to design the sensors, the sensors and overall system were validated in 1963 by the Small Boy shot of Operation Dominic II. A small nuclear weapon was detonated at the Nevada Test Site with a set of three BAS sensors mounted around it, adjusted for greater than usual sensitivity due to the unusually small yield of the test weapon. They were connected via Las Vegas to the operational BAS network, and as expected detonation alarms were promptly displayed at the Pentagon and Ent and Offutt Air Force Bases of the Strategic Air Command, which at the time would be responsible for a reprisal.

I have unfortunately not been able to find detailed geographical information on the system. The three Master Control Stations for the Western United States were located at Helena, SLC, and Tulsa, per the nuclear test report. A map in a Western Union report on the system that is captioned “Theoretical system layout” but seems to be accurate shows detector coverage for Albuquerque, Wyoming, and Montana in the Western region. These would presumably correspond to Sandia Labs and Manzano Base and the Minuteman missile fields going into service in the rural north around the same time as BAS.

The same map suggests Eastern master control stations at perhaps Lancaster, Charlottesville, and perhaps Greensboro, although these are harder to place. Additional known target areas monitored, based on several reports on the system, include:

- Washington, DC
- Baltimore, MD
- Dover AFB
- “Classified Location” (relocation site? Camp David?)
- Ft. Richie
- Dow AFB
- New York, NY
- Atlanta, GA
- Hunter AFB
- Charleston AFB
- Homestead AFB
- Suffolk Co. AFB
- Westover AFB

[1] This system, called USNDS as a whole, has a compact space segment that flies second-class with other military space systems to save money. The main satellites hosting USNDS are GPS and the Defense Support Platform or DSP, a sort of general-purpose heat sensing system that can detect various other types of weapons as

well.