Surviving The Cyber Age

Chapter 3 - Actuators

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What can they see and what might they do

In this chapter, we explore the capabilities of threat actors in terms of what they can sense and acts they can undertake. We focus on the maximum capabilities and most malicious intents, but it's important to recognize that any particular threat actor other than a 1st tier nation state alliance is likely to have only a subset of the total capacity described here.

Actuators: the actions they can take

Now that we understand what can be sensed, the next question is what can be done. At a technical level, in terms of cybernetic systems, we are talking about actuators.

- Sensors can sense things that cybernetic systems cannot observe.
  - We can probably actuate anything sensors can sense.
    - *Example: we can probably induce signals equivalent to the signals received by sensors from a galaxy.*
  - But we cannot produce all phenomena that cybernetic systems can observe.
    - *Example: we cannot produce an actual galaxy today.*
- Cybernetic systems can observe things that sensors cannot sense.
  - We can probably actuate a mechanism to cause a cybernetic system to observe anything it can observe.
    - *Example: we can influence a cybernetic system to 'see what it wants to see', like a unicorn.*
  - Even if we cannot induce the signals required for the system to form this observation based on data from its sensors.
    - *Example: even if we cannot actually produce what it wants to see, an actual unicorn.*

There is a difference between what you observe and what is really out there, and this can be exploited by cybernetic systems.

Physical actuators

All actuators are ultimately physical in nature, but that is not what we are discussing here. These are different sorts of actuators that cause changes in physical properties, essentially ignoring the indirect implication of those changes. They come in different sorts.

Size as an issue

As an introductory note, actuators come in sizes from 'nano' to 'vast', neither of which is a technical term of any sort. Here's a range:

- **Nano** at the molecular level and smaller. As sizes get smaller, effects like surface cohesion become more important than gravity, friction, centrifugal force, and so forth. Actuators today can be built through nano-manufacturing to be so small that they float on the wind. And there are even solid substances that are lighter than air that can act as platforms to float nano-actuators at very small size through the smallest cracks in doors. They can do all the mechanical things identified below and can often be operated with electrical, optical, or other force generators under control.
- **Vast** at the level of using nuclear explosions to redirect a larger mass in outer space to destroy or redirect something even bigger, and possibly even larger knock-on effects.

States of matter

When we think of actuators, we usually think of solid objects or more complex things composed of largely solid objects. But actuators can involve multiple or different states, including in general, solid, liquid, gas, plasma, and others.[1] As an example,

- Water is liquid state is used as an actuator in many ways, from a leveler when things are floated on it, to a spray similar to sand blasting (sand is a solid), to a fluid coolants for saws and other cutting tools, and so forth. Oils of various sorts are used to lubricate many mechanical actuators, and can also be set on fire and used to produce gas through heating or chemical reactions.
- Gasses of course are used for all manner of things ranging from igniting under control to heat water or homes, to a freezing agent, to a balloon filler, and on and on as well.
- And plasma has all sorts of uses, including as an example, heating of materials to generate signals for measurement of concentrations, welding, and fluorescent lighting.
- And there are also other more exotic states of matter, like liquid crystals, ferromagnetism or antiferromagnetism, Bose–Einstein condensates and Fermionic condensates (in extreme cold), neutron-degenerate matter (in extreme density), and quark–gluon plasma (at extremely high energy).

Composites that form actuators are commonly made of components of different states of matter operating together. As a result, it is important to think of all the complex machines that use multiple states of matter to act on the environment they operate in, and to consider the environmental factors that limit their use. For example,

- At low temperatures, many liquids turn to solids, which makes them poor lubricants in those conditions.
- Pressure has effects on many fluids (water as it turns out is non-compressible) and of course on gasses. But it also impacts state changes, for example, pressure can turn liquids to solids.

Environmental conditions

We note the equation PV=nRt (pressure times volume = the number of molecules times the constant R times the temperature), which allows you to actuate to manipulate one or two of pressure, temperature, and volume as leverage to change the other two or one. Some actuators use these physical principals to induce state changes in actuators of the things they effect. And the environments suited to different actuators are, in many cases, subject to these sorts of constraints.

All components are subject to operational constraints associated with the environments in which they operate, and in many cases, different operating environments can have dramatic effects on the acts produced by the use of the same actuators. Aluminum, as an example, burns[2] very hot, and is highly combustible in some conditions. Careful with that aluminum foil!

1 https://en.wikipedia.org/wiki/State_of_matter is a good starting point
2 https://apps.dtic.mil/sti/tr/pdf/ADA425147.pdf “A Summary of Aluminum Combustion”, M.W. Beckstead, Paper presented at the RTO/VKI Special Course on “Internal Aerodynamics in Solid Rocket Propulsion”, held in Rhode-Saint-Genèse, Belgium, 27-31 May 2002, and published in RTO-EN-023.

Mechanical

Mechanical actuators exist at scales ranging from nano (molecular scale) to the largest devices people make, like ships which, although they have multiple actuators within them, can themselves act as actuators, for example in the destruction of the Francis Scott Key bridge in 2024. Essentially, anything that moves under control is potentially a mechanical actuator. This includes:

- **Kinetic weapons** ranging from bullets and other similar projectiles launched by chemical processes, rail guns, slingshots, or other things that cause high impulses to interact with targets (which is to say they hit you).
- **Openers and closers** of all sorts, which can open and close anything from a microscopic opening, to your hotel door (let or not let you or others in or out), an elevator door, a window, heat or air conditioning duct, underwater hatch on a boat, toilet bowl refill valves, and by now you hopefully get the idea.
- **Latches, locks, and fasteners** are another class of actuators that prevent openers and closers from working (for example) or hold things together. Automated systems using these for access dominate corporate and hotel access, and control many homes.
- **Pressure-based mechanisms** like valves and pumps that cause motion, typically induced by electrical or chemical processes, but sometimes by heat through expansion or focused light and so forth, or by other pressure-based mechanisms such as the power brakes on many cars. Also recall that PV=nRt in many situations can be used to effect other actions or their prevention through the environment
- **Levers** of all sorts that amplify motion and redirect it elsewhere. The extends beyond a fulcrum and a board to include all sorts of mechanical advantages, like a block and tackle that leverages a low force high distance rope pull into a high force lower distance rope pull (in proportion) or other motion, and a screw which translates rotational motion into linear motion, and of course the inverse of these things.
- **Burrowers** are common in the plant world and mechanical versions have been built to burrow through other things. In essence, they have splinters that slide through in one direction, but when you try to pull them back, refuse to go. The more things shake and move, the further in they get. Similar mechanisms are used for fasteners of some sorts. And of course ratchets are forms of burrowers as well.
- **Tools of the trades** including legitimate (carpentry, plumbing, etc.) and illegitimate (e.g., burglary), rotating machines like motors, and you name it.

Some other examples are provided online[3] and more can be readily found. These sorts of actuators have many exotic uses, like; a thin device that you slide under a door and that pops up and allows you to open the door from the outside by turning handles and locks[4]; snake-like tools that flex and bend their way through your body to get to internal locations then cut, close, and carry things in and out to perform operations[5]; and effectively robots that can be put in your blood stream to find and kill undesired cells; and on and on and on.

3 https://en.wikipedia.org/wiki/Actuator is a good starting point
4 https://lockpicktools.com/under-the-door-tool-2-0-shipping-u-s-only/ is an example
5 https://pmc.ncbi.nlm.nih.gov/articles/PMC4469288/

Sound and other waveform actuators

Technically, sounds are produced by mechanical actuators producing waveforms in a media. And of course, waves can be created in media in frequencies people cannot hear, and thus are not, perhaps, sounds.

- **Sound waves** for people are typically from about 10hz (cycles per second) to 20Khz, depending on the person, and in dogs and other animals there are different ranges. Aging tends to lower the top audible frequency for people.

  If a tree falls in a forest and nobody hears it, does it make a sound?

  - It's a matter of how you define the term sound.
    - If you define it as something someone or some thing hears, no
    - If you define it as vibrations in a media in certain frequencies, yes.
    - Oxford dictionary: "vibrations that travel through the air or another medium and can be heard when they reach a person's or animal's ear." - yes.

  - It turns out that there are lots of things that can be done by actuating sequences of sound waves. The MKULTRA project[6], a CIA effort revealed in Congressional testimony explored things like using sound as a weapon and for crowd control, you can use it to cause people to have to defecate, to make them upset, to calm them down, and of course if you add linguistic elements, to hear what they want to hear, or what you want them to hear. By projecting from multiple angles, you can cause focused sound to make people hear voices in their head that others around them cannot hear.
  - By sending sound waves in resonant frequencies with objects and at high enough volume, the objects can be made to break (for example sound breaking glass), heat up, generate other sounds in different frequency ranges, move, or otherwise act in various ways. Using multiple sources in concert, the waves can add, subtract, or otherwise interact from different directions, producing localization of the more substantive results.

- **Ultrasound** is higher than hear-able frequency sound used for seeing within the body and through and within other structures, as well as for medical treatments and other vibrational effect. For each of these, there is one or more emitters that vibrate, usually focused in a direction through a parabolic or similar 'speaker' or similar element, that either bounces the waves off of different surfaces listening for the returns (as a sensor requiring an actuator), or delivers focused energy to a region of space (as a pure actuator). Depending on the energy level, just like sound, more or less localized effect can be generated. From seeing babies growing in the womb to destroying cancerous regions in the body, high frequency sound waves are effective actuators.
- **Waves in water** and other fluids are generated by any number of actuators, from pool robots that clean pools to most boats and ships, which generate waves with their motivation mechanisms and movement of displaced fluid. If you can cause an earthquake (perhaps by releasing energy in faults with explosions), ...

6 https://all.net/journal/deception/MKULTRA/www.druglibrary.org/schaffer/history/e1950/mkultra/index.htm for details

- **Ground waves** have been used for long distance communication as well. The Ground Wave Emergency Network[7] (GWEN) was a cold war system used as an emergency backup to communicate across the US in case of nuclear war. They were pretty certain hitting the ground really hard could be measured by seismometers at a great distance. One bang for yes, two for no perhaps? Ground waves operate over long distances because the soil and rocks composing the surface of the Earth are of consistencies that allow vibrations at low frequencies to pass through them without excessive reduction in energy delivery. Earthquakes as an example produce ground waves that can be readily observed in desert and similar areas by simply watching as the wave propagates across the media. If you don't believe you can communicate this way, stand reasonably close to a jackhammer or vehicle that compresses soil and feel the ground shake.
- **Explosives and shock wave actuators** range from pop guns to nuclear weapons, and include essentially all explosive devices. Various weaponry is used for creating shock waves, typically in conjunction with loud sounds and flashes of light, and so-called bunker-buster bombs largely produce effects by disrupting underground soil and structures. These devices tend to not be reusable like many other actuators, so there are inventory and related aspects, but they are usually fired from other actuators or cybernetic systems. They can also be planted in advance for later activation.
- **Localization of sound (and other) waves** is a result of degradation with distance through media and wave interference patterns associated with interactions of waves at different frequencies and from different sources.
    - A sound wave at about 256 hz (middle C) traveling at the speed of sound in air (about 343 meters/second at standard temperature and pressure) has one cycle every 343/256 = 1.34 meters. At a higher frequency, say 343 Khz, a sound wave cycle takes 1/1,000 of a meter, a millimeter (about 4 hundredths of an inch). By focusing multiple synchronized directional sound beams of that frequency toward the same location, an area of less than a millimeter will have higher energy (by a lot) than anything else around it, allowing a small spot to be vibrated apart. Anywhere else, the maximum energy caused by the beams will be the energy of an individual beam (to the extent that they are well enough focused to not cause interactions elsewhere), and of course deprecated by the intervening media as it travels further through the media.
    - Waves also get focused by things like the shape of the area they vibrate in, and bounce off of different surface interfaces instead of penetrating through them to greater or lesser extent.
    - Note also that wave tops and bottoms are the high energy points, and these cover a smaller portion of the wave form location than an entire wave length. While energy over time is the sum of all the energy at a location, at any given moment, the energy is the sum of the energy from each of the waves present. If 10% of the waveform is of high enough energy when combined with other wave forms, targeting and synchronization is harder, and the energy burst is shorter with a smaller locus of combined effect.

7 https://en.wikipedia.org/wiki/AN/URC-117_Ground_Wave_Emergency_Network has some details

Electrical and optical

Most modern physical actuators are initiated and controlled electrically or hydraulically, and in many cases, these involve computer control mechanisms or other similar digital mechanisms. Here are some examples:

- **Analog systems** take in analog (continuously varying) signals and produce analog outputs using the configuration of electrical components to provide cybernetic control functions.
  - A common example today is the **night light** that turns on when the light sensitive transistor senses too little light and turns off when it senses too much. These mechanisms are often analog, and you can tell this because the light turns on and off slowly and partially dimmed as the external light source fades and grows. This is a case where the analog electrical actuator works with the optical actuator to control the amount of light produced.
  - **The power grid** is a larger scale example of an analog electrical actuator that is composed of many analog electrical actuators of various sorts that do things like; change voltages (transformers) and as a side effect currents; trip circuit breakers when currents exceed thresholds (these mechanisms often involve sensor mechanisms as well), generators that turn mechanical flows of air, water, or other media into electrical currents at voltages through rotating machines; and solar power generation that takes sunlight in and turns the photons (from light) entering the mechanism into currents at voltages. Power generation, transmission, and use are almost entirely operated on analog actuators.
  - **Communications (other than sonic)** operates almost entirely through analog signaling electrical and optical mechanisms. For example, digital communications ultimately produce analog signals, even between internal circuit elements, and essentially every physical output of any digital component is analog at some level of physicality. These mechanisms produce wave forms that trigger devices to go into various levels of voltage and current that typically use hysteresis[8] effects to maintain an apparent digital ‘state’. Electromagnetic waveforms are used for frequency modulation in FM radio and amplitude modulation in AM radio to transmit signaling on carrier waves, and these operate through antennae for transmission.
- **Finite state (digital) machines** (FSMs) are the heart of digital mechanisms of most sorts but generally not discussed at the systems level. They store a current state in the form of electrical charges, voltages, physical positions of electrically controlled devices, field effects, or other electrical and/or magnetic and/or optical properties, take inputs as wave forms or relatively stable values over limited time frames, use those inputs to make decisions about changes to state values, and produce outputs, typically in the form of voltages or currents.
  - Most computing devices are relatively low voltage and current (less than 12 volts and milliamperes or less).

8 Hysteresis is a term describing an effect where the energy to get over (or under) a threshold is less than the energy required to go back under (or over) that threshold. Thus it tends to be “sticky” in the region (state) once it is entered. There is normally a nearly linear process between the sticky regions to get to the other sticky state. This is how magnetic memory works as well as most circuit-based digital memory and switching..

- FSMs often connect to other finite state machines or peripheral devices through electrical elements that amplify the power levels to match characteristics of the mechanism being actuated. Each circuit component is an actuator feeding other components.
- FSMs, at the digital level of analysis and understanding, follow a different 'physics' than the physics of analog continuous systems and usually involve finite time granularity and because they are digital, finite values (0 or 1) for each 'bit' they represent.[9]
- Most modern digital systems are composites of FSMs called; central processing units (CPUs), network and other peripheral controllers, random access memory (RAM), read-only memory (ROM), and peripheral storage elements; internal clocks that keep other elements synchronized; and other components like internal 'bus' controllers for interconnections between components; that are themselves composites of individual switching circuit elements.
- Almost all such components have at least one sensor for converting external input into internal digital values and at least one actuator that provides output to other components, and this is true at every layer of the digital composite between its internal components and between composites.

- **Industrial control systems** (ICS) are usually electrically controlled cybernetic systems that take inputs from process sensors and produce outputs to process actuators, causing the processes under control to operate in an intended manner based on their design. These tend to be customized to the inputs, outputs, and specific desired functions of the control system. For example:
  - If the objective of these systems is to keep a motor operating within a range of speeds by applying more or less gasoline and timing sparks, subject to the input of a 'gas pedal', the mechanism will pour more (or less) fuel on the fire (gas on the sparks) and run the sparks at a higher (or lower) rate properly timed to the operation of the engine to respond to the peddle, while limiting the maximum and minimum speed of the engine by refusing to apply no gas or more than a limited amount of gas per unit time.
  - Such systems are usually far more complex and control things like temperatures and pressures of multiple steps in a process, for example in a chemical plant. By altering these mechanisms or through accidental or intentional failures, the plant or components of it may be made to explode, produce different properties in resulting plant outputs, or have a wide range of other effects. Look up Bhopal India for an example of this.[10]
  - Each of these control outputs acts through an actuator specific to the mechanisms under control. For example, they may turn valves to let chemicals into a mixing chamber, control a robot arm positioning and the paint sprayer the arm directs toward a car being painted, control a motor that runs a conveyor belt, and so forth.

9 https://infophys.com A chapter from. https://all.net/books/2013-DFE-Examination.pdf F. Cohen, "Digital Forensic Evidence Examination", 2013 (5th edition)

10 https://en.wikipedia.org/wiki/Bhopal_disaster https://pmc.ncbi.nlm.nih.gov/articles/PMC1142333/ and more...

- **Operational technology** (OT) is a more recent term for a wide range of industrial and non-industrial control systems and mechanisms that produce physical effects.
  - Every modern auto mechanic shop is full of these sorts of actuators, from the lifts to the air-powered tools, to the electronic testing machines, and on and on.
  - Every modern warehouse has these sorts of actuators, including on their automated fork lifts and pick and place robots and the mechanisms that control them, automated doors, conveyors, sorting machines, labeling machines, boxing machines, and so forth.
  - Every modern factory has electrically controlled actuators, as do grocery stores, any facility with fire suppression systems, controlled entry and exit doors, elevators, escalators, and other electrically controlled movement mechanisms.
  - Automobiles are operational technology platforms increasingly controlled by computers actuating system components like brakes, gasoline or electrical power flows, motors that push the car, motors that control windows, automated door locks, seat adjusters, entertainment systems, and so forth.
- **Internet of Things** (IoT) technologies are generally understood to be small low power devices individually controllable over the Internet, as opposed to controllable through an overarching specifically designed control system. Examples include:
  - **Home automation** mechanisms of all sorts invoke actuators, like: remotely controlled lighting; electronic doorbells and door locks; alarm systems; sockets that are used to control non-IoT devices; garage door controls; many modern ovens, refrigerators, toasters, and other appliances; automatic fire and water leakage detection and response systems; home elevators and lifts; home Internet WiFi systems; and on and on. These use a variety of actuators associated with each specific application.
  - **Office systems** like printers, facsimile (FAX) machines, label makers, computer displays, projectors, telephone and intercom systems, electronic advertising displays, time cards (where they are still used), standing desks, and so forth have similar sorts of actuators, and often use the same actuator and other IoT technologies as home automation systems.
  - **Hobby kits** are commonly available for less than $100 and typically include an assortment of actuators and actuator control mechanisms for linear actuators and DC motors, light emitting diodes and other displays, servo motors, haptic output, and more. Individual actuators of all sorts are available for under $100 and often under $10 depending on specific requirements. These are. In turn, connected to mechanical devices that become the actuators for these systems at higher power ranges.
  - **Makers groups** have projects running anything from model trains to wheel chairs, and many companies form from the inventions or applications of these systems to address specific problems. They commonly use IoT actuator devices to control larger systems and mechanisms, and are a great place to learn about a wide variety of actuators and how they are integrated with other devices to form new sorts of actuating mechanisms with cybernetic controls.

- **Lasers**, (Light Amplification by Stimulated Emission of Radiation) at high intensity, can be used for melting, cutting, power transmission, or communications.
  - **Lack of beam divergence:** Lasers have the advantage of not diverging substantially from their direction over long distances, and this makes them particularly useful for long distance communications, if you can properly aim them. Note for example, the speed of light has substantial effects for laser communications with the moon which is about 1.3 light seconds from Earth. So between the time you transmit and it arrives at the Moon is 1.3 seconds. The moon travels around the Earth (relative to the Earth as a stationary frame of reference) at about 1 kilometer per second.[11] As a result, in order to hit a spot on the moon, you have to aim where it will be, not where it is. To avoid being hit, you have to vary your speed and/or path a bit, but not by that much at a long distance.
  - **Frequency range:** Because lasers can operate at optical or higher frequencies and cut or 'etch' patterns in other materials and be controlled very precisely, they are used to manufacture integrated circuits. Lasers operate at wavelengths as small as 0.15nm[12] ($2.5*10^{-10}$ meters) which means that, for the purposes of etching to create integrated circuits and other applications, these actuators can act at sizes only 3 times the distance between the nucleus and the electron in a hydrogen atom in ground state. So actuators exist that can act at almost the size of the smallest atoms, way below the size of most complex molecules and the smallest living organisms (viruses). The lowest frequency lasers to date operate at 5.1 MHz[13] which is the frequency range of short wave radio (part of the 60-meter band).
  - **Energy transmission:** This lack of beam divergence also means that the energy of the beam at its origin is still there with relatively less loss than other optical beams at its destination. This makes it an ideal actuator for energy delivery, whether supplying energy for use or destruction. And of course this light need not be at optical frequencies, so you might not see it coming at you.
  - **Low powered optical lasers** have been used **for malicious purposes** as well:
    - Lasers have been shined into driver and pilot eyes from a distance to cause temporary (or permanent) visual impairment. Of course this is illegal in most places. But as a weapon, it can cause vehicle crashes and harm individuals.
    - Similarly, shining a laser pointer at most cameras will cause them to be unable to visualize other activities in the scene. Often, the laser is bright enough to the sensors in most cameras to force many/most/all pixels to their maximum sensory input values, so the whole screen looks bright white. However, in many cases, while this is observed by the human looking at the image, the actual effect of the laser is compensated to a limited degree by filtering mechanisms and adaptations of the lens opening, etc. so that some image may be recoverable by image processing methods.

11 https://coolcosmos.ipac.caltech.edu/ask/176--How-fast-does-the-Moon-travel-around-Earth-
12 https://analyticalscience.wiley.com/content/news-do/x-ray-laser-boasts-shortest-wavelength-ever 2025-09
13 https://www.nature.com/articles/s41598-025-88699-6

- **Lights and displays** and other **optical emitters** include a variety of technologies that use different amounts of power and emit different frequency ranges of light at different ranges of intensity levels and can change frequency and/or intensity at different rates.
  - **Flashing lights or patterns** can cause seizures in people with specific disorders, such as people with photosensitive epilepsy. They often also make people ill or cause other discomfort. Similarly, 'flicker-vertigo' is a disorientation-, vertigo-, and nausea-inducing effect of a strobe light flashing at 1 Hz to 20 Hz, approximately the frequency of human brainwaves.[14] Florescent lights can also cause similar effects. Photophobia[15] can also cause many effects induced by light and patterns of light.
  - **Visual dizziness**[16] is a widely observed phenomena, induced among other ways by inconsistency between what you perceive from your eyes and other senses.
  - Many **visual deceptions** are also produced by control over displays, and there is an emergent field of deception based on false images and image sequences, often called '**deep fakes**'.
  - **Displays shined on media** include things like display glasses that show graphics on top of direct visuals from the environment, displays on walls shone from small display generators, laser scanned on a mist in the air showing apparent 3-dimensional (3D) images, holographic displays, and more. These can also be used to provide information to sensors so as to trick the sensors into sensing things that produce observables not reflective of physical reality.
  - **Light emitted from drones** include swarms of, typically unmanned arial vehicles (UAVs), that emit different lights moving around a 3D space, creating arbitrary large-scale images.
  - **Fireworks and other explosive displays:** These are used for fun, but may also be used as threats, distractions, or for other purposes ranging into the military domain.
  - **Deceptions at large scale:** In World War 2, control over lighting and other displays were used to cause pilots to aim at the wrong targets. This was especially effective in the Battle of Britain. Of course today, other targeting technologies are available…
  - **Displays as a weak point in user interaction:** Examples of false displays used as actuators for influence are less unusual than you might think. However, one of the most publicized examples is the destruction of nuclear fuel refinement facilities in Iran by the "Stuxnet" attack.[17] In this case, while the supervisory control and data acquisition (SCADA) system displayed a normal situation, the actual information on the activities of the centrifuges being used to refine Uranium would have indicated they were going to destroy themselves, which eventually they did.
  - **Focused combined optical waveforms** are very similar to sound in that they can be directed, especially in lasers, waves from multiple beams added over small focused areas, and so forth. Optical frequencies lead to similar distance equations, but the frequencies of visible light are in the (4 to 8)*10^{14} hz (400-800 terahertz)

14 https://en.wikipedia.org/wiki/Flicker_vertigo
15 https://my.clevelandclinic.org/health/symptoms/photophobia
16 https://balanceanddizziness.org/disorders/vestibular-disorders/visually-induced-dizziness/
17 https://en.wikipedia.org/wiki/Stuxnet which points to many other papers on the subject.

range, with the speed of light about $3*10^8$ meters/second, so the distance for focal areas are on the order of 10^{-8} meters, the size of individual molecules and very small viruses. Targeting at that scale is problematic of course. But because normal light diverges so much over distance, overlapping light beams can be very bright over larger areas, and worrying about nano-scopic targeting areas is not usually of interest for non-laser light beams.

- **Light is how we see things**, as should be obvious by now. But it's also operable at frequencies we cannot see and other vision systems (animal and other sensors) can see. As such, frequencies we cannot see can be projected to other entities that can see it without our knowledge, and right in front of our eyes. This can be used, among other things, to communicate between cybernetic systems that just happen to pick up frequencies we cannot, making inputs to other systems appear different from what we perceive them to be.

These various sorts of actuators come in different varieties, many able to be automatically actuated, others requiring human actuators along the way. They are often networked through communications mechanisms using protocols (defined sequences to express specific actions and responses). They often form cybernetic mechanisms on their own and connect to be part of larger cybernetic mechanisms. Essentially every mechanical actuator can be found in the control of such systems. In addition to their use in control of other mechanisms, electrical actuators directly control electrical devices such as:

- **Pacemakers** and other medical devices contained within the body.
- **Tasers** and other electrical actuators directed toward shocking targets.
- **Electric** chairs and other electrocution mechanisms.
- **Shockers** intended to warn or provide non-lethal or controlled shocks include things like heart defibrillators which save lives (or can stop hearts if applied that way), Electromyogram (EMG) devices that are used to sense nerve conductivity and can force physical movement of body parts, mild shock warning devices, electric fences, and so forth.
- **Scanners** such as Computed tomography (CAT) scanners, Magnetic resonance imaging (MRI) devices, functional MRIs (FMRI) and other similar devices use electromagnetic mechanisms to emit electrical, magnetic, or optical wave forms that their respective sensors detect.
- **Radar and related emission devices** that emit electrical, magnetic, or optical wave forms that their respective sensors detect.

The number of variations on these devices is vast, and these are only examples to help get a sense of the things that can be actuated. Each has potential for abuse, causing harm ranging from inducing spasms and (epileptic) fits, to permanent tissue damage, to behavioral changes, and of course physical burning and death to individuals. When used in larger scale systems such as infrastructures they can cause mass power outages, temporary malfunctions, permanent equipment damage, and knock-on effects from these and other similar outcomes of actions.

Infrastructures

Infrastructure elements include things in power grids, telecommunications systems, oil and gas pipelines, educational systems, financial systems, Internet services, health services, emergency services, and others. Here are some examples for each of these infrastructure types:

- **Power grids** use actuators like transformers, capacitors, resistors, inductors, transistors and other similar junction devices, circuit breakers and closers, automatic re-closers, and other electrical components the turn power on or off or transform voltage and/or current levels, match frequencies, or provide safety mechanisms for failure in a safe mode (failsafe devices).
  - **Generators** are actuators that produce electricity from energy sources, usually by processes that produce side effects of heat and chemical residuals. They are powered, in most cases, by the energy source, in some cases, after being started by an alternative mechanism, and controlled by control circuits that limit the energy source flow rate or control the voltages and currents of outputs,
    - **Gas and similarly powered generators** are usually started by a spark igniting a volatile fluid or gas that explodes in a cylinder forcing a plunger to move a mechanical mechanism that turns a rotating magnetic device to cause current in a winding that produces a desired voltage and current through a transformer. Once started, the generated power produces enough energy to yield output as well as causing the next spark to explode the next load of fuel, and so forth. Output is controlled by limiting fuel available to be burned and changing the output transformer for voltage and current control.
    - **Flow powered generators** like water and wind generators are turned by the force of the fluid or gas flow moving or turning a mechanical mechanism that turns a rotating magnetic device to cause current in a winding that produces a desired voltage and current through a transformer. In this case, no spark is required, nothing is exploded, and the only waste produced is the heat, wear and tear on the mechanisms, and reduced energy left in the flow material. Output is controlled by limiting the flow of material into the mechanism, often by the use of control valves or gates or other similar mechanisms and changing the output transformer for voltage and current control.
    - **Nuclear power generators** usually operate like flow powered generators, with the flow, usually of a gas, produced by heating fluids to boiling point thus producing increased pressure in the gas that produces flow that turns the magnets that cause currents in the windings, and so forth. The heat in this case is produced by the nuclear fissile materials being placed in close enough proximity to produce a chain reaction producing heat and ongoing chain reaction. The trick is to control how much heat and limit the chain reaction so as to not allow it to grow too large and too hot so as to melt down the reactor and produce lots of undesired radiation. This is done by using control rods that absorb some of the neutrons that cause the chain reaction and controlling the control rods so as to allow the desired amount of energy to be produced.

Production can also be limited by limiting the amount, richness, and shape of the fissile material so as to create a reactor that cannot melt down.

- **Direct current generators** include devices like solar panels that directly convert light into direct current (DC) electrical power. Solar panels are made of semiconductor materials, typically silicon, and are encased in glass and aluminum frames for protection. The semiconductors operate through the photovoltaic effect that directly transforms photons hitting the semiconductor into electrical current.[18] Many modern systems come in panels with built-in DC to AC (alternating current) converters for easy integration into home power systems, while other cases store the DC power in batteries or other storage mechanisms, such as pumping water up to a tank that can later feed a water-powered generator to get back electrical energy. Different approaches have different efficiency, but since the sun continues to shine, efficiency is only an issue to the extent you cannot store enough power between daytime and night to run through the night on what was stored. Many current systems also sell back energy to the power grid operators to reduce power bills for the owners of the homes or other generation facilities.
- Other power sources are available as well. This includes things like geothermal, tidal, earth motion, diamond nuclear, and a range of other technologies that work in different ways to produce electrical power.

- **Transformers** use different numbers of windings of inductance coupled wires to transfer power from one winding to another while changing voltage and current levels along the way. The change in voltage is proportional to the ratio of windings, and the change in current is inversely proportional to the change in voltage after loss (they emit heat and vibrations) due to the inefficiency of the system. So going from from 100 windings to 200 windings will double the voltage (you can think of voltage as pressure) and halve the current (you can think of current as flow rate). By moving a physical connector from winding to winding, transformers can change the winding ratio and thus output voltage and current. Transformers operate in both directions, so lower voltages can be turned into higher voltages with an appropriate reduction in current as well. This only works for AC circuitry...
- **Junction devices**, among other things, allow DC voltage controls. A typical transistor in active mode, for example, takes an input voltage at its 'base', and forces the output voltage (at its emitter) to be a small amount less (typically 0.2 volts for silicon NPN junctions for example), by controlling the voltage differential between the collector (the source of the power) and the emitter. It does this with little loss from heat and is thus more efficient than other methods of voltage control. And it does it by using a (usually) lower current control voltage to control a (usually) higher current output voltage, thus it acts like an amplifier. There are many other junction devices used as actuators and to control higher powered actuators, like generators and switching systems.
- **Circuit breakers, opener, closers, and re-closers** are typical switching systems used in power transmission. A circuit breaker is designed to open (disconnect) an

18 https://en.wikipedia.org/wiki/Solar_panel is a good starting point for deeper understanding

electrical path, usually by a mechanical device physically separating wires or a connection between wires when certain conditions are met, such as excessive current, voltage, or temperature. If the device can be reset, it can actuate again and again, and if it cannot, it will have to be replaced once it acts. Circuit openers do essentially the same thing, but they are triggered by control mechanisms rather than environmental conditions. Circuit closers close (reattach the wires in) circuits that were previously open, again under some sort of control (manual or not). Circuit re-closers are typically automated closers that close circuits previously opened by breakers in case the breaker was triggered by a short-term spike, and thus removing the requirement to manually or through an external control mechanism, reset breakers every time they trip. A lightning strike, for example will tend to trigger a breaker, but it doesn't last for long, and an automatic re-closer can save a lot of time and money for these sorts of transient events. Re-closers typically only try a limited number of times over a period of a few seconds at most, and if they fail to gain stability, stop trying to re-close the circuits.

- **Frequency matching synchronizers** are devices that match the waveforms of multiple electrical power feeds to allow them to be connected together without causing undesired side effects associated with adding waveforms, and to avoid high currents that may burn things up when one high energy circuit has a high positive voltage and the other has a high negative voltage with respect to it.[19]
- **Waveforms embedded in electrical systems** are used to transmit signal along with power. For example, in home lighting systems, signals are sometimes sent between devices by higher frequency low voltage transmissions in the same wires used to send the power to devices. Over long-haul power lines, similar signaling has been used, but more typically today, a fiber optic cable is wound around the power cable for signaling and communications purposes. Because the fiber optic cable carries light (photons) and the electrical cable carries electrical current (mostly electrons moving), there is little or no interference between the systems (photons and electrons don't normally interfere with each other, but temperatures in the power lines may effect the fiber as media). Of course higher power waveforms may also go through power infrastructure.
- **Electromagnetic pulses** are waveforms actuated by weapons such as nuclear blasts and special purpose devices. They tend to be very short time and high energy, and the result is typically damage to circuits and devices that control or are connected to electrical systems. The waveforms are high frequency which means they tend to pass through much of the low frequency (60hz) mechanisms of electrical infrastructure and spread a long way through power systems. It is not unusual for them to have effects hundreds of miles from the source of the pulse.
- **Standing waves and positive feedback** issues in electrical infrastructure, as well as other electrical equipment allows voltages to build up over time as periodic waves add to each other at resonant frequencies. Like other waveforms, these can build up to high enough voltages or induce high enough currents to damage components, not only within, but connected to, the power infrastructure.

19 https://en.wikipedia.org/wiki/Synchronization_(alternating_current) is a good place to look for more details.

- **Fail safe devices** of various sorts are used in power systems as well. Circuit breakers are one example, but because power systems normally flow power from higher to lower voltages and voltages may change rapidly over time, for example when a breaker opens a major circuit because of a short circuit to ground through a connection with a tree branch or a line break during an earthquake, the power change in one place produces a wave of energy back flow and forward flow up and down the wires from the fault. These tend to be high energy surges and the waveforms going back through the wires cause the generation, transformation, delivery, and switching systems to have physical effects. Examples include back force on motors, voltage spikes and drop-outs, temperature effects, inductive coupling, and so forth. Some such devices have fail safe mechanisms so that when they fail, they fail in a safe mode, such as not blowing up the generator, by disconnecting or shunting excess energy from the more harmful effects.

- **Telecommunications systems** use actuators in the form of line, circuit, and packet switching devices; provisioning actuators; and radio (including other transmitted wave form) systems.
  - **Line switching** is less used today than historically. It uses a single path (usually 2 or more wires) between the endpoint and a switching center, and the connection is switched from line to line to line as it goes between switching centers until it reaches the line to the other end. It has the advantage of being a dedicated pathway at full bandwidth all the time it is connected. However, it has the disadvantage that at the switching center, it is too expensive to have every possible connection available all the time, so when there are a lot of connections in use, you might be blocked from connecting.
  - **Circuit switching** is like line switching, but instead of line to line connections, multiple signals (identified as circuits) are transmitted and received over the same line. Switching centers separate the circuits for independent routing, so that circuits entering on the same line might leave on different lines. This shares the bandwidth of a line between circuits, each circuit with a reservation of fixed bandwidth. Many circuits travel on each line. ‘Trunk’ lines between switching centers usually handle many more circuits than the line from and to your house. This has the advantage of more flexibility in directing traffic and rerouting the traffic during outages or overages. But it still has limitations on the number of circuits, each circuit being given a fixed amount of bandwidth all the time. At high loads, circuits become unavailable just as lines did in line switching.
  - **Packet switching** segments communications into small chunks called ‘packets’ (no surprise there) that are independently routed through a (usually mesh) network. This is how the Internet, Asynchronous Transfer Mode (ATM), and other packet switched networks work. These are normally digital signals, so that the analog signal at the source is turned into a digital signal via Analog to Digital (AtoD) converters, the digital signal is then transmitted electronically, optically, or by radio using a signaling protocol to switches, each switch directing each packet toward its destination in a flexible routing manner that rapidly compensates for congestion and outages by sending packets through different paths. A major advantage is no fixed limit on connections or traffic volumes between endpoints (other than the total

available bandwidth on the set of paths between them) and a queue-based system with prioritization so that, for example voice can go with relatively constant delay, while data can go in bursts. But at the end of the day, there is only so much actual bandwidth available at each point, and as traffic gets congested, your traffic may be slowed to intolerable levels. There are also all manner of other problems in this venue that are not present in the simpler switching methodologies.

- **Provisioning** systems are systems used to configure settings on systems throughout communications networks using automation to replace human processes. As an example, a cellular telephone used to be provisioned by the sales site calling the telephone provider and getting a series of numbers to enter into the phone to give it a unique identification and authorization used by the switching systems and radio towers to identify and track usage (which was charged by the minute). Today, cellular devices are pre-provisioned, and as they connect to the network, additional provisioning cycles, including automatic updates, are transmitted over the cellular connection. The same sort of processes happen in the digital infrastructure today, with provisioning using the same networks used for communications traffic to do updates and set up systems of interconnection and operation.
- **Actuators over time** in telephony went from manually controlled switchboards with human operators plugging in wires, to a physical dial that produced a series of ‘clicks’ on the line that caused relays in switching centers to switch lines, to sounds generated by key presses on a push button phone that were sent over the wire to dial a call, to the modern ‘smart phone’ which actuates packets in response to touch or voice commands. These actuators are part of the ‘signaling system’ which controls the network as opposed to the traffic on the network. Phone ‘Phreakers’ found out, among other things, that blowing a whistle that was given as a prize in ‘Captain Crunch’ cereal was effective as an actuator for engaging the signaling system and could be used to place free calls, change provisioning, and all manner of other network control functions. The need to separate signaling (control) from traffic (content) was well established at that time for security purposes, and ignored in the Internet age. As a result, control in the Internet travels over the same packet system as content, and the Internet is susceptible to the same sorts of control attacks.

- **Oil and gas (and other) pipelines** use actuators to control the flow of material, usually based on pressure, temperature, and other physical phenomena to partially or completely open and close valves.
  - **Flow controls** are typically either ‘bang-bang’ actuators that fully open or close something, or continuously variable actuators that use motors or pressure-based mechanisms to turn valves, move gates into different positions, switch flows in and out of different pipes, and set pressure release valve settings.
  - **Pressure controls** typically use; relief valves set to release material and thus reduce pressure, with that release (hopefully when the material is dangerous) going to a storage container or ancillary flow path; pressure differential mechanisms that control volume to change pressure (PV-nRt again), either by having a pump, gravity

flow, or other different-pressure area force more material into or out of a pipe or by changing the effective size of the pipe by changing the openings between segments using flow controls; or by generating or using more or less material.

- **Pressure waves in pipes** are the result of pressure differentials between different locations equalizing by the flow of material from higher pressure areas to lower pressure areas. The speed of wave propagation depending on the properties of the material, so that oil is likely to propagate pressure differential waves more slowly than water or gas. Just like other infrastructure systems, actuators changing pressure or flows can cause waves that can cause physical damage if the pressure differentials get high enough.

- **Financial systems** use special purpose systems for supporting the societal monetary mechanisms. This ranges from paper to electronics:
  - **Automated Teller Machines (ATMs)**[20] are used to deposit, withdraw, and move money between accounts as well as check balances and other similar informational purposes. They act as actuators to replace bank tellers who normally would not be available 24 hours a day 365 days a year (one more day on leap years). They have; actuators that take in, scan, count, and dispense cash in different denominations to and from areas within the machines; actuators that take in identification cards and (usually) return them; actuators that display various information; actuators that communicate through infrastructure to internal financial records systems to verify validity of and execute transactions; an internal vault that can be opened and closed by actuators; and alarm mechanisms with actuators that make noise, call police, or whatever.[21]
  - **Vaults and safes** in banks have actuators that allow them to be opened, closed, locked, and unlocked. They normally also have actuators for alarm functions. The actuators for various kinds of locks include a dial or other input mechanism, that actuates tumblers, sliders, ratchets, and/or other mechanical and/or electrical mechanisms that ultimately actuate or enable actuation of the latching mechanisms that keep the door open or closed. There is usually a big handle for moving the big mechanical actuators that slide out the mechanisms that hold the vault door closed. Internally, there are often safe deposit boxes with key-based locks that actuate the lever that allows the individual boxes to be removed and locked back in place.
  - **Transportation vehicles** such as armored cars are used for large amounts of cash, fungible instruments, and other valuables. Like other cars, they have engines and wheels and so forth. But they tend to be armored for financial activities, designed to a specification to make it hard to rob them or physically interfere with their progress form place to place long enough to get away with enough value to be worth the likelihood of going to jail.
  - **Printing presses** and related devices (don't try this at home – it's illegal) are used to produce physical bills and coins. They take plates combined with special ink and

20 Note the overloading of ATM for Asynchronous Transfer Mode and Automated Teller Machines. The same abbreviations and terminologies are often used across different fields for different meaning based on context. Content in context produces meaning, or some such thing.

21 https://en.wikipedia.org/wiki/ATM is a decent article to start from

paper, add watermarks and other security measures to counter forgery, and produce sheets of bills that are then cut and stacked and wrapped, (or stacks of coins). Presses of this sort push inks and other things into the paper or other material that is the substrate of bills, usually with great force, so that the materials penetrate and become embedded within the paper or other substrate of the bills. They run in motorized systems and at high speed with feeders, aligners, bill numbering that changes for each bill, and other similar actuators placing the paper stamps and pumping the other items placed within the bills all in the right quantities at the right places and times. Automated cutters slice up the sheets of bills into the right sizes with the right edgings, and stacking and wrapping machinery acts to create the output that is then physically transported to other locations such as warehouses, banks, etc. through transportation vehicles. Other paper financial instruments are produced in much the same manner, but monetary bills are a special class.

- **Electronic mechanisms** are used fo the vast majority of financial transactions and monetary value today, as it has been for quite a long time in most Western countries with strong telecommunications infrastructure in place, including before the Internet ever existed. Trading on stock exchanges is no longer done so much with slips of paper, but rather with digital protocols between computers. The actuators are electronic components that cause a trade to happen. Because the value of things like stock in exchanges changes with every trade, time is of the essence in getting a trade into the sequence of trades, and as a result, special purpose computers placed as close as allowed to the system of records that records the definitive authoritative version of what happened when, have the advantage of time. Recall, the speed of light is $3*10^8$ meters per second, so every meter further away puts you about 3 nanoseconds behind the competition. And it does make a difference that adds up over billions of trades.
- **Internet financial services** support much of the financial world today, allowing almost anyone with Internet access and a bank account to move money around. Credit cards are also supported in this manner, and the Internet was a great boon to the ability to carry out more transactions with less effort, thus having a positive effect on spending which is usually translated (by economists) into a positive effect on a growing economy. More things being bought and sold is a direct result of the reduced cost (in time and effort as well as money) of transactions, leading to a reduction in friction for actuating a transaction. These mechanisms are the major actuators in the financial world. In 2024, there were something like 791 billion credit card transactions[22]. The four major US card processors facilitated $26.116 trillion in global consumer transactions in 2024.

- **Health services:** Actuators in health services range over a vast spectrum, from pills you swallow to prods that poke you, all sorts of mechanisms are used to act for and on people. Research and development in health care produce vast numbers of new devices and treatments, leading to about 500,000 patent applications per year[23] with China leading the charge producing about 4 times the number produced in the US, and

22 https://capitaloneshopping.com/research/number-of-credit-card-transactions/
23 https://insights.greyb.com/healthcare-patent-landscape/

the rest of the world significantly lower numbers. Every modern ambulance has a stockpile of actuators ranging from tongue depressors to automatic defibrillators, and hospitals typically have thousands of different kinds of actuation devices ranging in function from patient treatment to laboratory services, diagnostics, food production and delivery, and even robots for things like restocking inventory at nursing stations. Areas most focused on today, in order of patent filings are material analysis, medical and dental preparations, diagnosis and surgery technologies, organic compounds, bio-molecules, other biotechnology, healthcare data systems, sterilization and disinfection apparatus, climate adaptation technologies, drug preparations, medical devices, medical implants and prostheses, physical therapy apparatus, biological testing methods, and medical therapies. Each of these produces some sort of actuators to cause some sort of effect. To drill down one level in this arena would take another 20 pages, but you get the idea.

- **Emergency services** save lives and reduce property damage, and use a wide variety of different actuators to do that. These services generally focus on responses to events, as the name **emerge**ncy implies. Events (stuff) happen(s) and bad things **emerge**. Responses have to be timely in order to be effective, and this calls for technologies that act in a timely fashion and with appropriate force.
  - **Fire response services** involve the **trucks**, **boats**, and **aircraft** that show up with their **sirens** blaring, and the water (or other compound) lines that get **hooked** up to **water sources** and **pump, produce,** or otherwise **flow** the water or other compounds through **nozzles**, sometimes from **ladders** or other elevated **platforms** or **boats**, to suppress and eventually cool the fire. Everything in **boldface** there involves actuators of one form or another, and we should remember that they are largely operated by **people**. Communications systems coordinate the fire response, and in things like forest fires, there are also fire axes, motorized cutters, backfire ignition devices, and more.
  - **Police** are usually the first responders to criminal incidents and civil disputes, and of course they help out all the other responders as well. They have actuators like guns, night sticks, sprays, tasers, and other weapons, as well as radios, vehicles, road flares, first aid kits and their contents, knives, and perhaps other cutting tools, tire irons, handcuffs or other restraints, and all manner of other things.
  - **Medical** emergencies outside of medical facilities combine health care capabilities with other response capabilities, often in ambulances (ground, air, or whatever type). In addition to the transportation vehicle itself with its sirens, lights, etc. other stuff is usually present. A quick internet search yielded some useful sites with lists:[242526272829] There are something on the order of a hundred different actuators involved. One of these lists includes:

24 https://emergencyresponseafrica.com/essential-items-in-an-ambulance/
25 https://www.parkwayeast.com.sg/health-plus/article/inside-ambulance
26 https://lifeline-ems.com/the-abcs-of-emergency-medical-kits-whats-inside-an-ambulance/
27 https://media.emscimprovement.center/documents/Equipment_for_ambulances_FINAL2125.pdf
28 https://codelibrary.amlegal.com/codes/minidokaco_id/latest/minidokaco_id/0-0-0-616
29 https://ems.utah.gov/wp-content/uploads/sites/34/2023/08/Paramedic-Ground-Ambulance-Equipment-Checklist-07.23.pdf

1. **Radio Equipment:** A two-way radio operating on a radio frequency authorized by the Federal Communications Commission (FCC). Operable between vehicle and headquarters, and the county sheriff's office, police department, and local hospitals.

2. **Safety Equipment:** seat belts, hardhats, fire extinguishers (dry chemical type), road flares (20 minute type), 3-cell flashlights, hand spotlight, car mounted spotlight, auto jack and tire wrench, tachograph recording device.

3. **Stretchers**: all level cot with multiple position backrest, 4 inch all rubber wheels, multiple standing levels, contour features, 2 sets safety belts, locking bar, and 4 inch foam mattress and pillow. Portable stretcher with safety straps.

4. **Blankets And Linen**: crash type blankets, wool or equivalent blanket for each stretcher, adequate linen for 6 complete changes, plastic covers for patients.

5. **Oxygen Equipment**: "H" tank of oxygen or equivalent, "D" tank of oxygen or equivalent, medical oxygen manifold, inhalator with regulator and humidifier, oxygen masks with hoses (2 adult and 2 pediatric), oxygen canulas with hose, mechanical resuscitator, resuscitator masks (1 adult and 1 pediatric), Mouth to mouth artificial ventilation airways for adults and children, oropharyngeal airways in adult, child and infant sizes, hand operated bag-mask ventilation unit with adult, child, and infant size masks. Valves must operate in cold weather and unit must be capable of use with oxygen supply, portable suction apparatus with wide bore tubing and rigid, pharyngeal suction tip, portable oxygen equipment with adequate tubing and adequate mask in adult, child and infant sizes, Connecting hose for oxygen supply for bag-mask resuscitator.

6. **Tools**: Pry bar, Hacksaw, wrench, 12 inch with adjustable open end, screwdriver, 12 inch with regular blade, screwdriver, 12 inch with Phillips type, hacksaw with 12 wire (carbide) blades, pliers, 10 inch vise grip, 5-pound hammer with 15 inch handle, 2 ropes, each 50 feet long and 3/4 inch in diameter.

7. **First Aid Equipment**: arm splints (pneumatic type), leg splints (pneumatic type), arm splints (padded board type), ice packs, combination urinal, bedpan, package paper towels, constricting bands, OB kit (1 pair of scissors and 2 clamps), bottle of alcohol, bottle zephiran chloride, Ace bandages: 8 6-inch., 8 3-inch, 8 2-inch., 1 dozen bandages, 5 triangular type bandages. Airways: large adult, small adult, infant adult. Spine boards: short with straps and cervical collar, long with straps, lower extremity traction splint with commercial limb support. Slings, padded ankle hitch and traction strap, orthopedic stretcher, rolls foil 18 inches by 25 feet (sterilized and wrapped), soft roll self-adhering type bandages 6 inches by 5 yards, 36 (8 inches by 71/2 inches) combination sterile dressings, 2-inch roller gauze, rolls (2 inch) adhesive tape, pairs of

scissors, rolls (1/2 inch) adhesive tape, bottle distilled water, bottle normal saline, poison kit, package ammonia inhalants, surgical masks, patient tags, restraint belt with cuffs, restraint belt, sandbags (2 by 4 by 12 inches), large sterile burn sheets, resuscitubes (1 child and 1 adult), stethoscope, blood pressure unit, mouth gags, universal dressings 10 inches by 36 inches.

8. **Technician's Bag**: A technician's bag which shall contain the following: bandage shears, flashlights (1 regular and 1 pencil type), small airway (or assorted sizes), large airway (or assorted sized), rolls 3 inch bandages, rolls 1 inch adhesive tape, arm splints, mouth gag, tongue depressors, infant oxygen face cone, assorted Ace bandages, 3 18-inch pieces surgical rubber tubing, 4 by 4-inch gauze pack, rolls 11/2 inch or 2 inch adhesive tape.

All of this, of course, fits in one ambulance, where the medics know when and how to use each of these, and where to find them during an emergency.

- **Rescue:** If you are being rescued, the rescuers have to figure out you need to be rescued, figure out where to go to rescue you, get there with the appropriate stuff to rescue you, find you there, get to you, get you and them out alive, keep you and them alive, and get you and them away from there to somewhere safe. This happens on and under water, in the air, in space, on and under ground or rubble, and/or in structures, and under a wide range of changing environmental conditions. Long ago, this might have been a dog fetching a person on a horse with a knife, and rope sort of affair, but today there are all sorts of actuators (and sensors) involved.
  - **Figure out you need to be rescued:** “I’ve fallen down and I can’t get up” is the line from the commercial for emergency alert badge and pendant actuators carried with individuals for instant emergency calls. Cell phones today have emergency calling modes as well as more advanced applications that, among other things, sense falls and crashes based on impulse levels and use these senses to actuate emergency service calls. You can call for help, others can call for you, and other emergency services can call for you. You might be reported by someone who saw you falling or your car flying over a cliff, and so forth. The reporting chain normally involves actuators of various sorts depending on the specifics. If you are in outer space, and there have been a few rescues there, it’s usually more a case of calling back to base for assistance in getting out of it by yourself. And underwater, things get pretty tricky as well.
  - **Where to go to rescue you:** It might seem obvious once they know you need help that they would know where you are, but even if they have a GPS position on you within a few inches, if you are in a cave, they will need to know where an entrance is, or perhaps where to start drilling from. If you are under water somewhere, they may know you need to be rescued, but finding you is often a lot tricker. Actuators of various sorts are commonly used to get sensors close enough to find folks who need to be rescued.

- **Get there with appropriate stuff:** If you are stuck in a fallen structure, today there are robots that can try to get closer to you and perhaps bring you a line of air and water. The legendary dogs that bring alcohol to skiers lost in the snow may be more legend than reality today, but search and rescue dogs bring people and things to people in rescue situations when people cannot get there directly. And there are all sorts of actuators used to get rescue workers to the places they are going to to perform a rescue. The television show “Emergency!” had a lot of different examples of this in different situations. From helicopters to boats to trucks to cars to rope lines, and all manner of other actuators involved, they are each involved in different situations.
- **Find you there:** Now that they have arrived in the 5,000 acres of forest where you were last seen, or the entrance to the cave you last entered, finding you in the location is sometimes a tricky task. Again, actuators bring sensors to proximity and then locate the not yet rescued.
- **Get to you:** Getting to a victim to the point where they can touch you, treat you, talk to you, or do whatever is required typically involves actuators like motorized hydraulic cutters and saws, tools like the jaws of life used in so many automobile accidents, rope lines, rescue baskets and hoists, air tanks and similar devices to allow the rescue team and victim to breathe when things get foul, and on and on.
- **Get you and them out safely:** The safely criterion is the tricky part here. In addition to the emergency medical actuators involved, as described above, the same sorts of actuators used to get to a victim are often used to get them back out of the dire circumstance into a more controlled one where additional medical assistance, transportation, and other supports are available.
- **Keep you and them alive:** Now that you are somewhere that is not about to kill you immediately, the rescue operation can do things like try to reduce or stop internal bleeding, keep your heart and lungs working, keep you from going into hyperthermia or shock, and so forth. Each of these involve various equipment with various actuators.
- **Get you to somewhere safe:** Transportation back to (usually) a hospital or other intermediate location where you can be relatively safe and start to recover most often involves the same sorts of vehicles used to get the emergency workers to you.

Infrastructures are packed full of cybernetic mechanisms of all sorts, and are critical to supporting most aspects of society, including many cybernetic systems that depend on them.

Physics

Of course all things can be potentially explained or understood at some level through physics, but here we are talking about things related to radiation and nuclear actions. So that includes generally undesirable things and desirable things.

Undesired things include, for example:

- **Nuclear weapons**, generally the **exploding** types, including the mass destruction strategic ones and the relatively smaller neutron bombs and tactical nuclear weapons.
- **Radioactive dirty bombs**, where the harm is not from the rapid expansion and heat but from the radiation, fear, and evacuation and treatment processes.
- **Electromagnetic Pulse** (EMP) weapons with pulses generated by nuclear events
- **Radioactive poisons** like those used predominantly today by Russia to kill defectors

These are usually considered weapons and are used almost exclusively by governments and attempted (so far) by terrorist groups and occasionally misguided students of physics.

Some of these seem really **desirable** for most of us for example:

- **Medical** nuclear actuators that deliver **treatments** such as radiation treatments to kill cancer cells at a higher rate than normal cells based on dosage levels, but can also cause harm (or death) at improper dosages.
- **Medical measurement** devices such as Xray emitters, Positron Emission Tomography (PET) scanners, and other similar devices that emit nuclear or radiological signals subsequently used for diagnostics, but with dosage controls that can release harmful doses are misused or abused.
- Measurements of age and origins such as **carbon dating** based on radioactive decay and emissions from things being dated.
- **Nuclear power** generation which includes producing heat to turn turbines to generate power and much smaller generation systems that produce electricity without turning mechanical devices.
- Nuclear material used for things like **fire or smoke detectors.**

The negative consequences of the weapons are fairly clear to most folks, but things like medical overdoses have killed people and caused illnesses and shortened lives, and these are within the capabilities of non-nation state actors.

Chemical

In the chemical / chemistry / molecular side of the world, there are an unlimited number of different things to create or exploit for different effects. Of course chemical processing facilities of all sorts mix chemicals in complex processes to produce other chemicals and reactions with and between them, which in turn produce different states of matter and temperatures, and many of these processes are now available at the microscopic level. Among the many sorts of things that can be actuated are:

- **Poisons** of all sorts can be created, ranging from wide spectrum killers to selective producers of illness of different sorts, noxious gasses, skin penetrating liquids and gasses that can carry other compounds with them. They are often used in fields and to fight pests and weeds, and produce nasty side effects over extended periods.
- **Stick and slick** chemical compounds cause things to stick to each other or slip and slide past each other. These can range from mild effects like a banana peel to variations where people and things end up slip sliding away, while on the sticky side,

they can get to the level of bonding where the interface is less breakable than the things it connects.

- **Suppressants** of various sorts are produced by chemical processes, ranging from fire suppression chemicals to foams of many different sorts. They tend to tamp down chemical processes, suffocating fire and sometimes other living things in the area.
- **Accelerants** tend to speed up processes, in particular combustion, which has a tendency to heat things up a bit., producing larger fires. The accelerant tends to be largely destroyed in the process as well.
- **Catalysts** tend to facilitate chemical processes enabling them to occur when they otherwise might not have. Unlike accelerants, they tend to remain at the end of the process.
- **Temperature manipulations** by heating and cooling, to extremes in some cases, are often results of chemical processes or a combination of mechanical and chemical processes. Getting things too hot or too cold causes a variety of effects, including explosions, equipment damage, warping, cracking, structural weakening, metal fatigue and migration, and a wide range of other other temperature-related effects across a wide range of materials and processes.

Obviously, without chemistry, biological life would not exist, and with chemistry we can have the same effect, or variations across the spectrum from improving to destroying people and things.

Biological

In the biological arena, actions come in the form of the release of non-replicating or replicating molecular and larger structures into environments.

- **Nano bio actuators** are typically molecules or particles that attach to the molecular structures of other biological organisms or change the local environment so as to alter the functioning of those other structures. Some such molecules just float around and, if in high enough concentrations, get close to or attach to living structures use chemical bonds and alter their functions. If they reproduce they are called viruses and do so by using the reproductive capabilities of the organisms they infect. These are now relatively easy to generate using mechanisms like gene splicing and nano technologies that assemble 3d structures at the atomic or molecular level. Once enough samples are available they are typically mass produced in vats configured with controlled environmental conditions, and distributed in all manner of physical enclosures. They may be deployed as different particle sizes by different means, and typically can range from aerosol delivery systems that float in the air and go with the wind to liquid and solid variants that get delivered in pills, shots, fluids, or other similar delivery systems. Once infiltrating hosts they will typically be reproduced by the host mechanisms and spread through contact with bodily fluids, through feces or urine, by microscopic seed pods, and so forth. Viruses generally fit into this category. As a general rule, they do not have their own metabolic mechanisms, which means as long as their structures are not destroyed by the environment they are in, they can persist in a dormant state indefinitely. They are typically so small you would require an electron microscope or a

similar device to see them. Their ability to alter the environment at very small scales can lead to damage to physical structures at the microscopic level.

- **Micro bio actuators** are typically larger in scale and have their own reproductive mechanisms and include some sort of protective barrier such as a cell membrane that allows them to carry their internal machinery (their own environment) with them, as long as they are kept in some reasonable range of temperature, pressure, light, chemical, and other environmental conditions. Some of them can go dormant for decades or centuries when in conditions that prevent reproduction or movement but don't destroy their structures. They tend to be metabolically active so they consume energy, use it to move, grow, reproduce, and otherwise act, and they produce heat and other forms of waste that they expel into the environment they operate in. We call them micro in this writing because they are generally not visible to the unaided human eye, but with an optical microscope you can usually see them. As they move about or otherwise act, they consume things from their environment, doing damage to whatever was there before, and leave waste that alters the environment, potentially harming other living things in their vicinity. Reproduction typically leads to exponential growth of their population in areas where they find food until available resources are exhausted, or of course a competitor destroys them or otherwise interferes with their ability to reproduce. They spread by going with the flow of the environments they are in, whether that is flying along with the rest of the expellants in a sneeze or passing out of a body as waste, or within a larger creature, by moving from structure to structure. Depending on the variant, the host may show few or no symptoms until the actuators infest multiple body parts and destroy enough structures to do permanent damage or cause death. They are generally intentionally produced by using vats similar to the vats used for nano-biological reproduction and are distributed in the same sorts of ways. To the extent they are intentionally customized this is typically done by altering an existing life form rather than attempting to create one from scratch through some sort of assembly process, at least as far as our current science goes. These actuators are often able to eat away at manufactured mechanisms such as seals used in joints. As a result, in some environments, rubber or other similar mechanisms used to flexibly hold together metals or make fluid-tight connections get eaten away causing equipment failures. An example is a recent breakthrough in fighting cancer with remotely enabled cells.[30]
- **Mini bio actuators** are typically of a size visible to the human eye, but more importantly, composed of multiple cells that combine to form an organism where different cells perform different functions. In this sense, they tend to be cybernetic organisms that have sensors, actuators, communications, and controls, although these may be highly distributed in nature. In that sense they might also be considered to have a level of intelligence, although not necessarily intent in the manner we usually use that term. An example of such an organism is a plant that reproduces by releasing seeds into the air or on the ground. If you watch closely, the seeds ultimately open up or drill into their environment and start to grow. If they happen to grow inside another biological organism, a battle will likely ensue, and the infiltrated organism will suffer some side effects. If they share resources with other organisms, then competition for

30 https://magazine.viterbi.usc.edu/fall-2025/features/remote-controlled-supercharged-cancer-killers/

resources may ultimately lead to a battle as well. These are always grown today, as opposed to being somehow constructed. They can be customized, for example by gene editing technology like Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR), which can open up DNA strands and replace their sequences. The edited genes are then reproduced by the normal mechanisms of cell division. They can produce a wide range of effects on the resulting organism, and those effects carry through to the external as well as internal mechanisms of the organism. For example, you could add an arm (not yet done), change the color of fur, and so forth. Prior to genetic editing, organisms were more slowly evolved by pairing parents (for sexual reproduction) or selecting more desired features (for asexual reproduction) and causing them to be more prevalent in the population. This is called selective breeding. Selective breeding of dogs, for example, produces different sizes, shapes, colors, and capabilities of dogs often customized to different purposes. Selective breeding of plants produces most of the human edible food today.

- **Populations** and **Ecosystems** are complex interdependent collections of biological organisms adapted and co-existing within a local region. Because invasive species are less susceptible to local organisms that have, over time, become specialized to survive by winning the battles against other species, they can often overwhelm indigenous plants or animals, destroying perhaps one species at first. This has a cascading effect on other species in the local environment, often killing off or overpopulating the area with various other species, which then effect other elements of the ecosystem. Some such species may also carry micro- or nano- biological elements that are toxic, such as rats carrying the plague, or Ebola (a virus) jumping to the human species, presumably from monkeys. Moths can devastate forests, viruses can kill human populations, micro-organisms can kill off crops, and millions can be killed worldwide in a matter of months by biological pandemics. History has many examples of biological attacks particularly against indigenous peoples. For example, in the Americas, infested blankets were given to native Americans who were killed off by the new diseases they had no resistance to. Biological attacks have ranged from intentional water pollution to aerosol sprays to gas attacks and beyond. With today’s technology, it is feasible to create very specific diseases that attack specific genetic profiles. Ultimately, humans living on Earth are changing the environment by their actions, favoring some places over others, accidentally or intentionally destroying the genetic diversity of the planet, and with knock-on effects that are currently often not predictable.

Biological actuators can be released intentionally and in focused ways by various physical delivery systems ranging in size from microscopic to massive. People can be used to spread diseases, as can animals ranging from ants to zebras. These effects can be limited in various ways, for example, by creating special versions that die off under externally controllable conditions, by inoculating some populations against them, or by exhausting their food supply as they kill of a targeted species. Attempts to introduce other creatures to limit the population of invasive species has produce undesired side effects, such as the cane toad in Australia.

Informational actuators

Informational actuators, in the sense here, are actuators that cause indirect effects. The indirect effects of those actuators are really what we are ultimately interested in here.

Because information technology is embedded within many cybernetic systems as part of their communication and control components, it can often explicitly direct actions of other actuators and thus directly cause the sorts of harms identified above. But in addition, through their ability to induce informational effects through content interpreted by living creatures and cybernetic automata, they can induce a far greater range of larger scale effects.

At a basic level, informational actuators can be analog or digital in nature. In reality, digital actuators are actually analog at the level of physics and circuitry. The main difference is that digital circuits are designed to limit the ranges of stable conditions so that they are interpretable as one of a finite set of distinct values, typically each such circuit element having two stable states, often identified as true or false, 1 or 0 (zero), but represented physically as charges, voltages, currents, orientations, visibility, waveforms, or other such mechanisms in physical media. Information actuators are then invoked by those analog or digital values interacting with and being interpreted by some mechanism. For example, an optical signal hitting a human eye produces internal (informational) signals in the human brain that in turn change internal states and flows producing indirect actions, ranging from a blink of the eye (at the reflexive level of the human cognitive system) to the decision to operate the body to whatever purpose, for example moving a steering wheel in control of a car. The same notional mechanism of a cognitive system operating at different levels of processing is true for computers, operational technologies and all manner of other cybernetic systems.

Some obvious issues are provided here as a starting point:

- As a general concept, informational actuators can induce or suppress signals at any location accessible by those actuators, and indirectly to any location accessible by the indirect effects. Since information can usually flow transitively (from A to B then from B to C, etc.) such actuators have the potential of spreading to an unlimited range of locations.
- Computer viruses are explicitly designed to reach the transitive closure of information flows, as are rumors. For this reason, the reproductive capacity of the informational actuator has a direct effect on the range of consequences attainable.
- Subject to the interpretation mechanisms of the locations informational actuators reach, anything the mechanisms they reach can effect may be actuated indirectly by the informational actuator.
- So-called general purpose computers are capable of performing any computation that any other computer can compute, and informational mechanisms reaching them have the potential to produce any output sequences and reachable internal states of the receiving mechanisms. Almost all widely used digital devices are general purpose in this way.
- Actions are not limited to each local mechanism reached, but may also be coordinated across multiple reached mechanisms for coordinated actions.
- Internal states and actions may not be readily reflected in external behaviors, and informational actuators my change internal workings of systems they reach without making those changes apparent in some or all external behaviors of those systems.

Here are some examples to help explore the space:

- **What you see vs. what you get:** You cannot be certain of what is going on based on apparent observable behaviors. For example, in the well known attack on Iranian centrifuges being used to refine nuclear materials, the information sent to the systems displaying the status and history of the processes were reflective of a simulated reality while the centrifuges themselves were self-destructing. Another example is current generative AI systems that claim a basis for what they state when the actual basis may be quite different, and in many cases the basis is just made up.
- **Supply (and demand) chain effects:** It is common for attacks on cybernetic systems to exploit the inter-dependencies between systems. This includes processes for getting and applying updates and new distributions. Alterations effecting systems in one place get deployed into the chain from there to the systems using them and the results of those alterations may effect the rest of the demand chain. For example, an information actuator that changes a single bit in a large code base once ended up disabling the AT&T national telephone network. You can imagine a change in some code base used as a library for other code bases that ultimately leads to targeting an individual financial transaction. But an even simpler technique is in common use today. Attackers gain access to an email server, intercept emails, alter then, and allow them to continue to the end user who acts on the altered version. This has been used to change the recipient account and routing number on financial transactions, charge a different account, change the quantity of a purchase, change the address an item is sent to, and so forth.
- **Cybernetic system behavioral changes:** For cybernetic systems that control physical processes, it's easy to see that: altering the information the system uses as inputs, the communications between components, or the control mechanism; can have effects ranging from; changing set points on individual parameters and causing the process to fail or work in a different manner than expected, to allowing material theft not reflected in the normal mechanisms of the system, to showing wrong values for temperature or pressures, to changing the timing of controls leading to positive feedback in the physical system, perhaps even leading to explosions. More subtle effects are attained in modern generative AI systems, which take 'prompts' in order to undertake actions. In these systems, so-called 'prompt injection' can be used to change their behavior transparently to the user. Similarly, systems that use training data to 'learn' can be mistrained, and most widely gathered training data has many mistakes, while intentional subversion of training data or other data used by these mechanisms causes them to behave in highly unpredictable ways, or in some cases highly predictable but undesired ways. Examples have been shown to alter financial transactions, change interactions with users, reveal confidential information, and so forth.
- **Financial effects:** The range of financial effects goes from individuals to whole societies. Obviously, by changing bit sequences in digital systems, any individual or account could be left with no money, more or less money, more or less credit or credit scores, more or less availability of accounts or actions, more or less purchasing power, and so forth. Other sorts of things to anticipate are false theft attribution which could lead to legal processes resulting in jail sentences or taking of property, market rise and fall associated with individual stocks or bonds, groups of stocks or bonds, or market segments produced as a result of rumors, uncertainties in the markets, and all manner

of other similar effects. Depending on access already available or gained through informational attacks, all of these and other similar effects are possible and have been demonstrated repeatedly.

- **Effects on individual decision-making:** What you see and hear dictates what you see as options and which you choose. This is one of the core facets of influence operations and it is widely exploited through techniques like 'false choice' where you are given a list of options, none of which include things the other side doesn't like or many of which are presented as so bad nobody sensible would ever choose them. Ths interested reader would be well advised to read "Frauds, Spies, and Lies, and How to Defeat Them".[31]
- **Physiological effects:** making you sick, feel well, injure yourself and others, causing behavioral changes that get you put away, etc. are all things that can be done with informational actuators controlling audio, visual, temperature, air quality, water quality, food preparations, and other actuators.
- **Reputational effects:** improving or damaging your interactions with other people and access to resources (human and other) can produce larger scale effects that cause people and systems to treat you differently. Things ranging from credit ratings, your stature in social media venues, public releases that get into the media, rumors, malicious gossip, and a wide range of other similar things can cause substantial damage to your ability to operate, especially with others. Being falsely accused is one of the worst of these things as it can do real and lasting harm, sometimes even getting to the point of sending people to jail for years when they are innocent.
- **Emotional effects:** inducing and suppressing emotions and getting you acclimated to terrible things and willing to do things you would not normally do is one of the most common things we see in human to human communications. It's how we move people toward and away from different decisions. The Big 5[32] us the most widely accepted metrics system for personality traits, and personality trait exacerbation is often easily accomplished. Today, generative AI can be told to explicitly exploit specific traits in forming communications and it will do the job well. Combined with psychometrics which are also automated through techniques like Linguistic Inquiry and Word Count (LIWC), automated influence operations can readily detect and exploit these traits. Recent efforts to influence have applied these emotional effects to great success, and this is used for advertising, movie-making, political campaigns, violence campaigns, divide and conquer tactics, voter suppression, and so forth.
- **Individual and group psychology effects:** Creating and destroying the ability to make decisions and get things done, group think, changing the pace of group operations, and driving people toward or away from objectives are just a few examples of the effects of information actuators. Organizational change typically takes time and goes through an adoption cycle. Even if top management changes the rules and fires people who fail to follow them, officious behavior and other similar actions often subvert these forceful methods. Subtler uses of information provide power to influence using positional and resource power including information, the right to access, and the

31 https://all.net/books/Frauds.pdf
32 https://en.wikipedia.org/wiki/Big_Five_personality_traits

right to organize along with expertise, charisma, and emotion to invoke exchanges, changes in rules and procedures, control of the environment, and personal magnetism. Resistance can be reduced by involving, informing, and preparing people for change. Buy-in operates at multiple levels of organizations based on trust, benefits, peer pressure, success metrics, and punishments and rewards. Compliance without choice leads to resentment, while identification stems from liking the person or idea and leads to positive feedback, and internalization is adoption that leads to ownership of the idea and helping its adoption by others. Each of these is achieved by informational actuators influencing individuals resulting in changes in the group as a whole.

- **Political effects:** Mass effects on populations and power stem from large-scale informational effects. Indeed the political process is one of convincing masses of people to favor one person, group, or party, and disfavor another. The ability to invoke different specific communications to each individual based on their psychological and behavioral characteristics, location, affiliations, and situation turns on information actuators that can leverage analytical results from sensory data and feedback from prior acts is now within the actuator capabilities of cybernetic systems.
- **Others?** Of course there are many other examples of informational actuators and their ability to effect and affect. Interested readers should review these referenced articles for additional details in the influence issues of informational actuators.[33] [34] [35]

And of course complex combinations of all of these actuators can be composed from components to create other actuators with multiple effects at multiple scales, independently or in concert, in areas ranging from nanometers to thousands of miles, and beyond.

The current capacity and potential future capacity of the technologies available today for actuation are so vast that it's hard to even conceive of some action physically possible and not attainable based on what we already know and can do. And of course ongoing research and development continues to expand the specific applications, components available, and possibilities within the grasp of human capacity to act.

33 https://all.net/Analyst/2024-02.pdf Breaking through the cognitive barrage
34 https://all.net/Analyst/2020-12.pdf Understanding a meta-language of influence
35 ***

