How to Shoot for the Moon and Land in the Stars

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Chapter 1

Why I Care - Network Earth

1.1 The Biosphere

Take a breath.

Washing into your lungs is a rich mixture of gasses containing the all important and life giving element - oxygen. While you may traditionally think of oxygen as coming from the plants around you, it turns out that the mixture swirling about in your lungs comes from a much wider and more exotic set of sources. The majority of the oxygen you

are breathing comes from our oceans - one in five breaths from a cyanobacterium named Prochlorococcus [27]. On the complete other end of spectrum are rain-forests like the Amazon - a place that produces something close to one in ten of your breaths [25]. The result of this is that the brew of gasses swirling around in your lungs has come from creatures smaller than the single strands of hair on your head to those as tall as multistory buildings. However, the story doesn't end there.

If you're near some kind of urban center, you probably deal with some level of pollution. The daily goings of urban living produce loads of pollutants such as nitrogen and sulfur dioxide. However, plants have a habit of pulling such pollutants out of the air and storing them safely away in their tissues. In fact a 2006 estimate found that in the United States alone urban forests were responsible for more than 3 billion dollars of air purification [6]. So while most of your oxygen was sourced from our oceans and rainforests, it's purification was local and done by the trees and shrubs in your back yard.

Take a bite.

If you happen to be eating cassava from South East Asia then you can thank a tiny parasitic wasp - *Anagyrus*

lopezi - that is reared in the millions to control populations of a devastating pest - the mealybug [32]. An enormous boon for both the financial and food security in the region, the economic value of this millimeter long wasp is more than $14 billion a year.

If instead you're dining on a lovely, flaky slab of wild salmon, you are effectively eating the entire ocean. As predators that sit relatively high in the food chain, they depend on "bait fish" like herring as their primary source of food. Herring feed on things like krill, who in turn eat the very plankton providing us with the majority of our oxygen. If any one of these levels in the food chain starts to experience issues so too does your flaky slab of salmon.

Finally, if there are plants on your plate there's a reasonable chance you can thank the leagues of beetles, flies, butterflies, and wasps managing pollination in our world. These services are supplied to an estimated 75% of crop species, and are worth something upwards of $200 billion every year [43]! Without the insects pollinating the plants that produce our food the variety in our diet would shrink dramatically.

Go on vacation.

Diving at a coral reef? The colors, the vivacity, the sheer brilliance of all the fish darting this way and that around you? It's thanks to the sharks. Sharks specifically target sick or unhealthy fish, thereby improving the overall health of fish populations and possibly preventing outbreaks of disease [41]. Furthermore, they help prevent the kinds of population explosions that lead to mass die offs. Just another way they preserve the fish we all love seeing.

Hiking alongside giant sequoias or passing through the incredibly diverse south african fynbos? Both of these are only possible thanks to the drama of fire and lightning. Sequoias depend on fires to open their tightly sealed cones and the resultant sprouts depend on the brush clearing power of the fires to give them any chance of seeing the sun [31]. Then, of the more than 9,000 plant species found in South Africa alone, many, like the proteas, also depend on fire to release their seeds and prepare the ground for the next generation of amazing [18]. So why do these fires occur? Lightning is the spark, but the reason the fires spread is thanks to the vast diversity of plants that leave behind dried out remains. When it comes to sequoias and proteas, it truly takes a village.

Enjoying all the ocean has to offer in Florida? Thank

the mangroves. Not only do mangroves provide nurseries for an incredible diversity of creatures including the fish that crowd coral reefs and the manatees and birds that people flock to see (pun intended), but they are also veritable buttresses against coastal damage. One estimate suggested that during Huricane Irma in 2017 they prevented over a billion dollars of flood damage! That's a lot of insurance.

Take a step back.

These examples are just a tiny taste of how *every single aspect of our lives* is deeply, intrinsically dependent on the living world around us - the biosphere. The Millenium Ecosystem Assessment identified 25 different categories of ecosystem services - and these are as broad as things like food provisioning and erosion control [2]! From millimeter wasps to three hundred foot tall trees, from ecosystems half a world away to the shrubs in your back yard, our world provides our food, water, air, health, happiness, and so much more. It is our life support system, our spaceship as we hurtle through the vast, cold emptiness that is space and for the first time in our history we have the power to overwhelm it.

1.2   The Anthropocene

Let's start with some perspective. We as human beings have a very hard time thinking about pretty much any period of time longer than the ones we've already lived. Tell me something is ten years old - no problem I can grasp that. Tell me something is one thousand years old? While I can make it out mathematically I really don't have any way to grasp just how much longer that is. 100,000 years? Forget about it. So let's use a frame of reference that's a little easier to understand. Let's pretend all of our universe's history fits in a single year [38].

From this point of view (and if we accept standard scientific time lines) the big bang starts us off at midnight January 1. The next four months are spent in a dizzying dance of expanding hot gas, newly forming stars, and, finally, galaxy formation with the milky way only showing up around May [10]. But don't assume that because of this our time line is about to speed up because we still have to wait until September before our solar system even forms! We've gotten roughly three quarters through our year and our planet has only *just* shown up. Surprisingly, given how long it's taken to get to this point, it only takes 20 days for the first things we'd deem living to show up, but then things slow down again as we have to wait until December (around 70 more days) before the first multi-

cellular organism joins the scene. Now things really start to take off.

15 days later we've got plants colonizing the land masses of our planet. 3 days after that the first reptiles join them. Only a mere two days later and we've entered the age of the dinosaurs. Think about that, in less than a third of the time it took to figure out how to make multi-cellular organisms we've gone from nothing macroscopic on land to dinosaurs! A day later, our ancestors - the first mammals - join the production and by December 30th (4 days later) the first primates appear.

But hold on one second. Did I just say December 30th? Does that mean we've got 1 day left in our year and humans haven't even shown up?! That's right. But it gets even wilder. Homo sapiens, us, don't show up until 12 *minutes* to midnight. Just chew on that for a second. All of human history, finding fire, inventing tools, starting the first cities, all the empires, all the wars, absolutely *everything* that our species has ever done occurred in the last 12 minutes of our universe's year. That's the amount of time it takes to heat up a microwave dinner!

But it gets even wilder because we, as a species, didn't figure out how to farm until 28 *seconds* before midnight. So really, everything you've learned about in your human history courses gets packed into about as much time as you spend watching a *single* tiktok. We are but a blip in

the history of our universe. But, oh, what a blip we are.

From nature's perspective, humans have generally been, with few exceptions, a footnote. There's a reason why the oceans were terrifying to early humans, or why people prayed to gods to stave off floods or famine. If nature decided to have its way, there was little we could do about it. But post the industrial revolution and especially since 1950, that relationship has *utterly* changed [10].

Let's start with some simple numbers. Around 71% of the land on our planet is considered habitable [36]. Of that habitable land we have put around 46% of it into agricultural production. That means we use a solid *third* of the planet's surface (not covered by ocean) to just feed ourselves. Except that we eat more than what's on the land. When it comes to fishing the picture is even wilder. Of global fish stocks we overfish 34% percent and maximally fish 60% [37]. That means there are only 6% of fish stocks that we could fish more without starting to deplete their numbers!

The amount of water we use is no less incredible than the amount of area we farm. Each year approximately 40,000 km^3 of freshwater flows into the ocean [10]. Of this only around 13,000 km^3 is accessible to humans with our current technology. Yet nearly half of that flows through human engineered systems! So not only are we using half

of the accessible land, and pretty much all of the accessible fish, we're using half the available fresh water too.

In the 2004 the International Geosphere-Biosphere Programme published a report that illustrated what is now called the Great Acceleration [15]. Across 24 distinct measures from total GDP to atmospheric carbon to the number of rivers dammed they found an explosive spike in activity starting in the 1950's. We've already talked about a few of them (farm, fish, and water use) but let's sprinkle a few more in for color.

Since around the beginning of the 1900's we've lost 30% of our forests. We've now dammed close to 25 thousand rivers. We consume about 300 million tons of fertilizer per year. Our global population has gone from 2 to 7 billion. And we have more than 3 times as many floods as we used to per decade. But here's the one that kind of summarizes it all for me - extinction rates have gone through the roof.

Extinctions are nothing new and in general pretty normal. As time marches on species come and go and that's... well... just evolution doing its thing. So what matters is not *whether* extinctions are happening but *how many* are happening.

In the past we've had some pretty spectacular extinction events. Around 444 million years ago the Ordovician-Silurian extinction took out around 70% of everything liv-

ing at the time [7]. 372 million years ago the Late Devonian extinction took out some 70% of all marine species. The Permian-Triassic extinction, which occurred roughly 252 million years ago, took out over 70% of everything alive again. Then in the Late Triassic (208 million years ago) we had yet another mass extinction. Finally we have the most famous of them all, the Cretaceous-Paleogene extinction where 66 million years ago over 60% of all species died as the result of a massive asteroid smashing into our planet and creating the equivalent of nuclear fallout. Bad for the dinosaurs but great for us as mammals often are attributed their place center stage thanks to that big old space rock.

Since we were visited by Armageddon-a-la-space extinction rates have pretty much held at their normal, background levels. Until, that is, the Great Acceleration. Since the 1950's extinction rates have skyrocketed to more than 1000 times their background rate [16]! At the current rate scientists estimate that 50% of all species could be gone by 2100. We have entered the sixth extinction.

Here is where our current impact on our biosphere really comes into perspective. Mass extinctions in the past have occurred as the result of insanely powerful events. Country sized asteroids smashing into the planet. Massive anomalies in global temperatures (sound familiar?). Such incredible dips in the amount of oxygen that more than

70% of all living species just... well... died of oxygen deprivation. Causing mass extinctions requires planet shaping power. *We now possess that kind of power.* And as a result we've entered an entirely new geological epoch, an epoch where humankind is the domineering, world shaping, power - the Anthropocene [10]. And in the perspective of our "universe in a year" we managed this power grab in less time than it takes to watch a tiktok.

Contrary to how you may be feeling, none of this is meant to scare you (although fear and awe are perfectly appropriate reactions). Instead it's meant to impress upon you the gravity of our situation. In the first section we got a glimpse of just how important the biosphere is to us and now you've got a taste of just how powerful we, as a species, have become - that asteroid that took out the dinosaurs is taking notes from us now. Thankfully this power means that in so much as we can absolutely wreck our world, we can also take care of it too. The problem is not that our world is doomed, but rather that we can no longer just take it for granted. Given our planet shaping capabilities we have no choice but to become active, conscious stewards of our planet. So the question is simple, how do we do that?

1.3 A Revolution

Suppose for a moment you have a garden. While at first it may seem like all you need to do is water your plants and let them flourish, anyone who's tried gardening before knows there's a lot more to it than that. For one thing watering is a tricky business. Water too much and your plants can get water logged and die. Water too little and your plants will wither up and die. Plant your plants too close together and they won't be able to grow properly. Plant them too far apart and you'll be wasting loads of garden space. Then there are the pests. Caterpillars, beetles, mice, deer, you name it it's probably trying to eat your plants and every single one of these needs a different strategy for dealing with. Then there's disease. Plants, like us, can get sick and it's especially likely if they're not getting the right balance of nutrients and care. Diagnosing these sicknesses is difficult enough that there are apps to help you with the task and then there are a whole slew of different methodologies to deal with the various ailments. And we haven't even gotten to the fact that choosing plants can be its own nightmare. Do you have enough sun? Too much sun? Direct or indirect? What's the soil quality, what's your growing zone? On and on it goes. Point is, stewardship of your garden requires a lot of specific knowledge about the plants you a growing, their

life histories, the life histories of everything they interact with, the place you live in, and so on.

So now replace your garden with the entire world. Obviously the amount of knowledge you need is going to skyrocket but something else changes as well. In your garden you've got lots of room to learn by trial and error - if you manage to kill a plant (like I tend to do) it's no big deal, just try again next year or in a different plot in your garden. We, however, have only one world. While we can certainly try little things here and there, at the end of the day, we've got to be pretty sure we know what we're doing before we launch large scale efforts to shape our world one way or another. And that requires models sophisticated enough to let us trial things in simulation. So not only do we need a lot of knowledge about how our biosphere works, we also need to make sure it's the kind of knowledge that allow us to build simulations. Turns out, this kind of science is pretty new.

Some history. The scientific revolution started in the 1500's and was set off by Copernicus' now famous idea that perhaps we aren't at the center of the universe [4]. What followed was a massive explosion in all things astronomy and over the course of a few hundred years everything we thought we knew about our place in the universe changed. In 1620 Robert Hooke discovered cells for the

first time launching the whole field of microbiology [45]. In 1735 Carl Linnaeus put together the system for classifying plants and animals that we use to this day and in 1745 Ewald Jürgen Georg von Kleist invented the first capacitor. Fast forwarding to the 1900's and we've got Max Planck's theory of black body radiation in 1900 followed quickly by Einstein's special relatively and his explanation of the photoelectric effect in 1915 - all theories that were seminal in the creation of modern physics. In 1953 Wilkins, Franklin, Watson, and Crick made the now famous discovery that DNA has a helical structure - thereby totally changing our understanding of the stuff - and in 1996 we cloned a sheep for the first time. So, given all of this progress, you might be surprised to learn that it was only in 1999 that Hans Schellnhuber published a "groundbreaking" paper on earth system modeling that spoke of a "second Copernican revolution" in our ability to model the biosphere [39]. Our first thoughts on this issue came around the same time as our ability to clone things and well after we came up with the idea of black holes in space.

To understand this we need to look at what was going on alongside each of these revolutions in science. The scientific revolution, with all of its progress in astronomy, came at the same time as the first telescopes were being invented. Hooke made his discoveries about the cell thanks to the newly invented compound microscope. Lin-

naeus only came up with his system of taxonomy after extensively traveling the world - something only possible thanks to all the nautical inventions that also created the "age of discovery". The first electrical inventions were all thanks to developments in what materials were becoming available as the industrial revolution unfolded [22]. The discoveries of modern physics were all thanks to continuous improvements in our ability to poke at smaller and smaller things using tools like the x-ray diffraction techniques that allowed Wilkins, Franklin, Watson, and Crick to infer the structure of DNA. The pattern from all of these examples should be pretty clear - to understand our world we need the tools to probe it and each scientific revolution has been attended by updated capabilities in our ability to gather data [22]. So it should come as no surprise then that one of the major tools used by earth system modelers - satellites - are a relatively recent development. As an example, the Landsat program, one of the largest programs to provide satellite imagery of Earth, only started in 1972 [44].

But satellites are only part of the picture and the need for further instrumentation and tooling is clear. Whether it's land management [14], pollination services [3], or general biodiversity management [13] (just to name a few) scientists in recent years continue to point to a lack of comprehensive data as one of the primary challenges they

face world over. Science is driven by data, and the data is sorely lacking.

So if we want to spark another scientific revolution, one that will give us the tools we need to be good stewards of our planet, we need to start providing the instrumentation required. So question is - how do we do it?

1.4   An Aside

Before we dive into how to develop instrumentation I want to stress something. The last section argues that we *need* models of our biosphere and all the attendant knowledge in order to be good stewards of our planet. I firmly believe this is true. However (and this is important) I *do not* believe that such knowledge should block actions that are already supported by the science that exists *today*. I *do not* believe we should wait to decarbonize or wait to stop wasting as much as we do or wait to stop polluting. These are all good, clear actions that should be taken *now* because the science clearly backs them. In general there will always be gaps in our knowledge that need filling, so if we ever want to be good stewards who actually take action we have to learn to listen to the knowledge we have.

Alright, back to the scheduled programming.

1.5 An Industry

We've got a problem. While pointing out the immediate need for biosphere instrumentation is cool and all, it's also laughably vague. How on earth are we supposed to execute on a mission statement that's that high level? Fact is, we need a strategy.

Strategies start with understanding our goals and, especially in our case, clarifying goals is really important. The history of conservation and "biosphere activism" has... well... a checkered past. Early biologists exploring the pacific islands sometimes caused extinctions in "the name of science" and part of the reason we're having to reintroduce wolves all over the place is that early conservationists helped get rid of them in the name of creating a more bounteous United States [30]. At the other extreme, in my own experience, I've found that frustration with human negligence often leads to a desire to take humans out of the picture entirely, a philosophy that culminated in the Half-Earth Hypothesis - a proposal that we should set aside half of the planet as a human free zone (and they're not talking about totally uninhabitable places) [46].

But let's look at intentions. The folks causing extinctions in the pacific islands? They just wanted to study birds. Unfortunately, at the time, studying birds was synonymous with shooting them. So while studying birds is

a great idea, shooting them all as a means to an end is a little more than short sighted.

How about the wolves? Well quite a lot of the money in conservation coffers comes from hunters. So making our forests more bounteous isn't a half bad idea. The problems are twofold. First, it turns out wolves are needed to keep deer populations healthy (ecology!). Second, extirpation is a really extreme take on "reducing" wolf populations. So once again, reasonable intentions with a short sighted strategy.

Finally I get the frustration with people seemingly just bulldozing everything that isn't "producing human good" or treating the natural world with less than respect. But the problem here is one of education - rather than understanding that rainforests are useful natural resources, most economies see them as unrealized cattle farms instead. The problem isn't that humans are included, it's that those same humans aren't including the natural world in their calculus.

Regardless of the various strategies taken, one thing is clear from all of these examples. The goal is to nurture the value that our biosphere provides us. Unfortunately this is still too vague for our purposes so let's dig deeper.

The Millennium Ecosystem Assessment [1] suggests a rather lovely framework for thinking about all of this.

They suggest (and the suggestion is backed by data) that human well being exists on a continuous spectrum with poverty that is made up of five key components - the necessary material for a good life, health, good social relations, security, and freedom and choice. So while you may have a lot of material wealth (1) if your health (2) is extremely poor because of, say, pollution, you are still impoverished to some degree. In other words there is no such thing as poor or wealthy. Instead there is a five dimensional spectrum that we have to keep our eyes on at all times.

As a quick example of why this is important, almost every assessment of ecosystems that I have read is stated in dollars. Even the first section of this essay had a dollar bent! But how do you put dollar values on social relations, feelings of security, or autonomy? You obviously can't! Having these five dimensions of human well-being helps us break out of the habit of only seeing value as economic. And this level of specificity and holism is exactly what we need in our goals.

Okay so that gives us a better sense of how to make sure we're measuring value completely, but how on earth are we supposed to connect this back to the literal jungle's worth of complexity in our biosphere? Trying to work out all the ways in which our biosphere provides for, say, our health brings the phrase - boiling the ocean - to mind. Clearly

we need to divide the problem up into more manageable parts. Once again, the Millennium Ecosystem Assessment is here to help [2].

As I mentioned before they have already done the work of divvying up ecosystem services into nice neat bins. At the top level we have three overarching categories - provisioning services, regulating services, and cultural services - which are each then divided up into specific sub categories such as food and fiber, water regulation, pollination, sense of place, disease regulation, and so forth. These, obviously, are much more manageable pieces of the overall biosphere pie.

Alright, let's bring this all back. How does this help clarify our path to building biospheric instrumentation? Well first we know now that there are 25 specific models that we are trying to build - one for each ecosystem service category. Second we know that in order to be complete, those models need to be capable of helping us predict the effects on each of the 5 dimensions of human well-being. Finally we know that those models need to be comprehensive. So we can clarify our path forward as such - we need to help scientists obtain the data required to build comprehensive models that connect each of the 25 ecosystem service categories outlined by the Millennium Ecosystem Assessment to the 5 dimensions of human well-being.

Which leaves a much simpler question - what data is required?

Here, we come to the kicker. Scientists have not exactly been twiddling their thumbs. Huge strides have been taken in learning how to think about and model this kind of stuff. Remember, the issue scientists have is not in having *no* data, it's in not having *enough* of it. Pull down the journal Ecological Informatics and you will find *hundreds* of examples of instrumentation techniques that scientists have already developed and proven useful. They've already done the de-risking work and know what data they need - they just need help deploying the instrumentation at scale! And doing this, would be a real value add.

Think about it this way. Most of us could, if we really wanted to, wire our own homes, do our own plumbing, and so forth. But doing so requires buying all sorts of tools, learning all sorts of techniques, going through all sorts of safety training, and so on. That's a lot of overhead for one house. A professional electrician also has to go through all of this overhead but then they apply their tools and training to loads of homes. This is the economy of scale - and it makes a big difference. We absolutely need this same economy of scale if we're going to attempt biosphere-wide instrumentation. And that means we need professional instrumentors. Put a slightly different way, to achieve the

economy of scale, biosphere instrumentation can't just be limited to a research activity - it needs to be its own industry, driven by its own professional workforce. To trigger the scientific revolution we want, we need to build an entire industry.

1.6 Conclusion

If we're going to be sophisticated stewards of our planet, we need a scientific revolution in biosphere modeling. Scientific revolutions in the past were driven by revolutions in instrumentation. Today is no exception. Our strategy? Using the 5 dimensions of human well being and the 25 ecosystem service categories outlined by the Millennium Ecosystem Assessment as a guide, find the researchers already building the instrumentation we need and create professional industries dedicated to deploying and maintaining that instrumentation at scale. Let's create a biosphere instrumentation industry - let's create Network Earth.

Chapter 2

Why This Book?

When I was a child, my family lived across the street from a wonderful little pond. Every time it rained our yard, the road, and, of course, the pond itself would become chock full of amphibians. I'd run out there in the rain and catch several of them to keep for a few a days in the bank of terrariums that my parents had purchased for my brother and I.

My brother and I just liked playing with them. We'd line em up and see which could jump the farthest, we'd build places for them to live with Legos, and before we let them go I'd take pictures of the patterns on their skin so I

could check if we'd met before. Then, after their short stay
was over, we'd bring 'em back to where we found them and
let them go on their merry way.

I like to think that the stay with us was pleasant for
them as much as for me, but I suspect that I got the lion's
share of joy out of those interactions. Indeed catching
critters was such a formative part of my life. I became
obsessed with learning everything I could about the living
world and had stacks upon stacks of National Geographic
issues, natural history books, and field guides. It seemed
obvious to everyone around me that I'd end up becoming
a biologist of some kind. However fate had other things in
mind.

Through a whole of series of events and existential
crises that seem as bizarre to me now as they did when I
was a hormonal teenager, at the age of 16 I found myself in
a dormitory at Worcester Polytechnic Institute (WPI) to
study physics of all things. But physics soon turned into
math and by the end I'd given up on that too and was
teaching myself software engineering and machine learn-
ing. Upon graduating with a math degree (I switched to
computers too late) I took up a role as a "Member of the
Technical Staff" at a telecommunications company that I'd
interned with the prior summer.

Over the next couple years I ended up being relatively successful as an engineer and even ended up co-managing the team I was on for a while (something I was wholly unprepared for). However throughout that period I just felt like there was something missing in my life and so,after another existential crisis or two, I ended up wondering if it was time to return to my roots - wildlife biology and conservation.

Thankfully I did the rational thing and decided to run a small experiment instead of just quitting my job wholesale - over the course of an academic year I took a marine biology course and a class in conservation. In the process of taking these classes I came to the realization that the kinds of technology I had been building over the past few years were almost completely absent from both biology and conservation. It was clear that those in the field could stand to take advantage of what I knew and so (at the advice of my professor) I started looking around for ways to volunteer my skills.

Over the next couple of years I volunteered with a bunch of different groups. At one point I helped a couple biologists automate a machine learning pipeline. At the end of that project it was clear that what we'd just

built could be applied to so many other things, yet that project (for reasons I still wonder about) just sort of disappeared. I ended up working with a marine rehabilitation group and after a couple of months doing a lot of manual, analog stuff that definitely could get automated started floating the idea of modernizing some things. I was very quickly shut down and left a few months later. At another point I started contributing to an open source project that was dear to me but quickly found that they were so overwhelmed they could only really hand off more trivial work to outsiders. Indeed in perusing their forums I quickly discovered that due to a lack of funding they had to shut down most of the more interesting features people using the tools wanted. All of this left a rather sour taste in my mouth. I couldn't get away from this feeling that I had so much to offer but no one seemed to have the time nor resources (and in some cases vision) to take advantage of it. Everyone was happy to take my money, or put my time to menial tasks, but no one really had a place for my *actual* skills.

So, after a time, I decided to take things into my own hands. If others weren't going to put my passion and brain to use I would - and after months of reading, talking to people, writing, prototyping, and thinking I came up with the idea for Network Earth. But as I began working on

that project something clicked in my brain.

The whole idea behind network earth is to create industries around the kinds of technology that can help us instrument our biosphere. There are 25 different ecosystem services to monitor and loads of technologies to manage in each. I suddenly realized that Network Earth didn't just solve my own problem, but it could provide a direction for anyone else in my position - and goodness had I met a lot of those people. When working at the rehabilitation center I'd been surrounded by *actual medical staff* who were being tasked with nothing more than doing laundry and mopping floors. In both of the classes I took nearly everyone there had loads of energy and ideas and each of them was looking for a way to help out. At work itself I was surrounded by colleagues anxious about the state of our world but unsure of how to become involved. So much skill, talent, passion, time, money, and energy with nowhere to go.

And so I had an epiphany that I probably should have had ages ago (but as they say, better late than never) - the real problem to solve here is not the biosphere stewardship crisis but how to harness all the energy and skill of those who *already want to do something about it*! If I could build the organization that I had spent the last few years looking

for I could harness that energy and end up being a much more effective force of change than if I built one specific technology to solve one specific part of the problem.

This, however, presented a problem. While I had some small amount of management experience I was totally unprepared to *build an organization from scratch*! I clearly needed to learn organization development and quickly. Thankfully the stars happened to align in my favor.

Learning anything comes in two parts - theory and practice. Without the theory there's no way for you to "stand on the shoulders of giants" and learn from those who've come before you. But without practice it's all in one ear and out the other. Theory I knew I could do, I'd just simply read everything I could about organizational development and management until I felt confident there wasn't much left that would surprise me. But practice was going to be the harder thing to sort out. Happily, at around the same time as this epiphany I ended up getting something of a promotion at work and found myself coleading a team of about a dozen people. And that team was tasked with building out a component of our broader organization that, up until that point, never really existed in any clear form. I found myself with a perfect mirror to the problem I wanted to solve - I had a group of brilliant

people who's energy needed to be harnessed toward an organization that did not yet exist. Ample opportunity for practice had just landed in my lap!

Which brings us to why I started writing this book.

This book serves two purposes. First, I'm a firm believer that you don't really understand something until you can explain it to someone else. Therefore I am using the process of writing this book to firm up my own understanding of organization development. However I am also a firm believer in self organizing systems. To my mind the best systems are ones that can build themselves and so, if I do end up being successful in building organizations, part of that success is going to come through teaching others, within the organization, how to build organizations themselves. When that time comes I hope this book will be a central resource.

So, this book is nothing more than the compendium of the things I've learned about organizational development. And while a lot of it is going to feel philosophical or abstract in nature you can rest assured that I myself lean upon these principles each and every day I spend leading teams, building organizations, and dreaming of a better world.

Chapter 3

How This Book is Organized

To me building an organization can be summarized as such - you start with a dream and know you've succeeded when you've made that dream actionable and you're executing toward it. As a result, building an organization is all about resolving the specifics of that dream. Like a sculptor who starts with a block of material, chisels out the general shapes, and then begins working on the details and textures, organizational developers start with broad questions and then work our way down to questions about finer and finer details.

This book then is an attempt to outline, as clearly and methodically as possible what those questions are, when to ask them, how to go about answering them, and what answers look like. However there are two dramatically different ways of presenting these questions that each serves a different, but very important, purpose.

The first is to build your intuition around why these questions exist, for what purpose, and why they take the form they do. This treatment is given in the first part of this book - **Intuition**. The second part of the book is far more practical. Theory is great and all but it can be hard to translate it directly into action to take. Instead, when it comes to actually putting things into practice, a manual is a far more useful tool. So the second part of this book - **Action** - attempts to play that role. As such it's not really meant to be read in linear sequence like a normal book, but instead to act as a practical reference for obtaining specific protocols to follow as you go about resolving your organization. However, without the theory it'll be terribly difficult to use the second section - hard to use a car manual to repair a car if you have no clue how a car works.

So, when you're using this book, consider taking the following approach. Read through the **Intuition** entirely

to ensure that you've got your bases covered and then, like you would for mending a car, use **Action** opportunistically, taking what you need, when you need it, and nothing more.

Happy reading!

Part I

Intuition

Chapter 4

Creating Catalysts

4.1 Skill

It's a reasonably well established fact that the average human being can only hold around 7 things in short term memory at once. Put another way, if I start sounding off digits to you in quick succession you'll only reliably be able to remember 7 of them at a time. However there are a rare handful of people out there who blow this number straight out of the water. There have been people who've been able to recite upward of 80 digits consistently and others who've been able to demonstrate this trick for 100's of digits at a time! Given the rather measly limitations on the

average human's brain you may be wondering what makes
them so special. The answer? Nothing at all.

For example take Steve Faloon - a student the psy-
chologist Anders Ericsson recruited to study how far peo-
ple can push their short term memory. When Steve first
started he, like the rest of us, could only reliably recite 7
or 8 digits from memory. Yet by the end of this exper-
iment he was reliably reciting 82 digits at a time! How
had he made this jump? By using mnemonics. Being a
runner, Steve realized that he could group series of num-
bers into running times. So if he saw the digits 1, 0, 3, 5
he'd remember the running time 10 minutes and 35 sec-
onds. This alone allowed him to focus on remembering
7 running times instead of 7 digits which translates into
around 28 digits overall. A huge leap forward! By contin-
uing to create structures like these that made better use
of his normal short term memory, he was effectively able
to extend his short term memory by over 10 times.

Another feat of intellect that seems near miraculous to
the rest of us is the ability of master chess players to play
blindfolded or without a board. Indeed many master chess
players have taken this to the extreme with some playing
a couple dozen games simultaneously all while unable to
see or touch any of the boards! Wondering what sets them

apart, a set of psychologists performed a rather interesting experiment. They took a national-level, mid-level, and novice chess player and showed them a board with a whole load of chess pieces arranged in a way that might arise from a game of chess. Then with the board removed they asked them to recall the arrangement of the pieces. Unsurprisingly, the better the person was at chess the better they did at remembering the pieces and where they were. But then they showed those same people a chess board with *randomly* arranged pieces, took the board away, and asked them to recall again. Surprisingly in this case there was no longer any difference in performance! The national-level chess player no longer had any advantage.

In interviews with a variety of experienced chess players, it has become clear that what they are seeing in their head when they play chess with no board are "chunks" of interacting pieces. They'll see setups that they are familiar with from prior games, lines of attack or pressure that have been important in the past, etc. And so when you randomly arrange the pieces on the board, none of these chunks can be found and so the ability to remember it with any level of real skill goes away - once again the exceptionalism is coming from specific mental representations that they've built up.

Ericsson and others studying exceptionalism have found this pattern over and over again pretty much everywhere they've looked. From swimmers being taught ways of perceiving their body and performance as they swim to musicians learning music theory to physicists learning the math they'll need to represent the universe - mental representations seem to be the key to gaining these incredible levels of skill. As Steve was finding ways to better take advantage of his limited short term memory so too are masters in all of these areas finding solutions that allow them to break through to the next level of extraordinary.

However, all of this should be setting alarm bells off in your head. If it's just a matter of learning mental representations, why on earth aren't we all master chess players and elite swimmers? Clearly we're missing something. To see what it is consider the pipe organ.

Playing the pipe organ (the kind you find in an old church) is no easy feat. There are usually multiple keyboards which you'll end up playing separately with each of your hands, a pedal board for playing notes with your feet, dozens of stops that control what *kind* of sound each keyboard produces, volume levers, and then of course there's the matter of actually playing itself - reading music, coordinating your fingers, keeping tempo, knowing how to

interpret the music, and so on. Clearly if you try to actively *think* about all of these things all at once you'll get overwhelmed. Instead you've got to make each of these components instinctive so that you can use your conscious mind to work on coordinating it all rather than trying to work out all the little details in real time. In other words you've got to work the underlying skills into your intuition.

Everyone who's practiced something knows that when you first start, whatever you're doing is *hard*. However if you keep up consistent and regular practice over time, what was hard ends up becoming relatively easy. Why is that? Well it has to do with the notion of homeostasis. All your body wants is for normal life to be... well... easy. So when it suddenly finds that every day you, for some unfathomable reason, find yourself running, it figures out that if this is gonna keep up it had better reconfigure things in order to make the run less of a pain. So it starts building blood vessels and musculature to turn your daily run into just another part of the norm. It shifts your statis state - your homeostasis.

Turns out the same thing happens for these mental representations we've been talking about. When you first start using them, your brain is rather clunky about it. Like the first time you did algebra or started reading you have

to think really, really hard to get things to work. However once your brain realized this was part of the norm it started shifting the mental representation from your conscious thought into your subconscious thought (which is far more effective and powerful) so that reading and algebra became relatively easy. However this takes time because you first have to establish that this mental representation is a new norm *and then* give your body the time to rewire properly. Going back to our pipe organ example we see that there are potentially dozens of individual skills that have to go through this process before we're able to play the pipe organ with any real skill. So take whatever time is required to embed one skill and then multiply it by the number of skills one will need to embed and you've suddenly got a sense of why we aren't all masters of every field out there - layering the skills required to master something takes a hell of a lot of time!

We can actually get a general sense of the order of magnitude involved in *just* the embedding process by looking at a skill that has an extremely well developed learning sequence by this point in history - classical violin performance. Given it's skill that's been around for at least a few hundred years, people have been able to take all the guess work and creative mental representation building that Steve was doing out of it. Therefore learning to

play the violin is really just a process of embed, embed, embed.

Ericsson and two collaborators Ralf Krampe and Clemens Tesch-Romer went to a well known musical academy and selected three groups of violinists - those who were the "best", those who were "better", and those who were "good". They then tried to search for what differentiated these groups from one another. Unsurprisingly, given all we've learned so far, the only predictive component they found was the amount of time people spent practicing - if you practice more you're better at playing the violin. However what's incredible is the sheer amount of time spent practicing. For those in the "best" category, given how much they'd been practicing, it was predicting that by the time they were going to be in their thirties (when folks start really rolling in their careers) they'd have put, on average, somewhere near 25,000 hours of practice in! To put that in perspective, even if you assume they've been practicing since they were 5 years old, that means they've been treating practicing as a part time job (20 hours a week) for their entire life! Embedding skills take a lot of time, energy, and dedication indeed.

This then brings us to Ericsson's conclusion - what leads to skill in any field is simply *deliberate practice*. He,

of course, does a much better job of getting at the specifics (and I'd recommend reading his book *Peak* [11] of which this section is a mere summary) but it more or less comes down to the idea that becoming skilled at something is about two things - (1) not reinventing the wheel, i.e. learning the mental representations that others have already invented in an order that they prescribe and (2) pushing your definition of normal deliberately and consistently in order to truly embed the skills you are learning into your body and brain. However if this is true than it also predicts something that would be rather liberating - that anyone can learn any skill. Note that nowhere in deliberate practice is there any notion of what we might call "talent", all there is is hard work and paying close attention to the coaching others can give you. So is he right, can anyone learn anything? The proof is in the pudding, so let's look at a positively wild example.

Perfect pitch is something that people will often treat more like a sense than a skill. Most assume that you've either got it or you don't. However in 2014 a Japanese psychologist decided to test this assumption. He gathered together a set of children between the ages of 2 and 6 who didn't have perfect pitch, and over the course of several months taught them how to identify 14 chords by just listening to them. For some children it came more

easily than for others, but eventually everyone could identify the 14 chords on their own. Then he tested the kids for perfect pitch. What he found was truly astonishing - every single one of the children had developed perfect pitch and could identify individual notes from sound alone! Something that had always just been considered talent was 100% learn-able!

The conclusion is clear (and if you want more evidence, once again, check out Ericsson's book *Peak* [11]) - anyone can follow in the footsteps of the masters if they're willing to put in the time and use deliberate practice. However this leaves us with a question - what happens when there are no longer any footsteps to follow? What if like Steven Faloon you're finding yourself having to invent the solutions that will bring you to the next level? What about creativity? Clearly if we want to under exceptionalism overall we will need to understand the creative aspect as well. So let's turn to that next.

4.2 Creativity

When we think about creativity we think about novelty - something totally new, a paradigm shift. Strokes of inspiration straight from the well of creative genius. As such,

it can end up feeling kind of haphazard, as if you must just mull over things until that stroke of inspiration occurs. Indeed it can end up feeling as if creativity is something given in droves only to a select few. Reinforcing this sense is the fact that most narratives about creativity are almost always dominated by a select few - cubism by Picasso and Braque, computing by Turing, relativity by Einstein. However, if we take a closer look at the achievements of these creative geniuses, patterns begin to emerge.

As an example, take Picasso. It's often noted that Cubism was inspired by the geometric and abstract nature of traditional African art, especially masks - something that Picasso took a keen interest in [35]. However, Picasso was only able to bring this style into the fold of more mainstream painting because he was one of the most technically proficient painters at the time. In similar fashion Jazz, one of the more influential musical developments in history, arose in New Orleans out of a melding of predominantly white, brass, marching bands and the music and dance traditions of recently emancipated African Americans [40].

On the STEM side there are examples like this as well. Probability and statistics started out as simple accounting for the purposes of playing cards and dice, but has sub-

sequently found applications in pretty much every field in existence. Signals processing is only possible thanks to a kind of mathematics called Fourier Analysis that is more or less the combination of the epicycles that early astronomers used to explain the cosmos and the principles of calculus that Newton developed [42].

Then there's all the inspiration taken from nature. One of the most successful optimization strategies out there - genetic algorithms - came from the flash of insight that if you can create a genome for different solutions you can find the best solution using the same principles backing genetics and macro-evolution in biology. Then there's the fact that down jackets are the result of realizing that some birds don't fly south during the winter, modern windmill fanblades were inspired by humpback whale fins, and there people are studying ants to figure out how to regulate traffic with autonomous vehicles [34].

All in all, the pattern here should be pretty clear - strokes of insight seem to come from taking the ideas from one field and then finding interesting ways of applying them to another. African masks + european painting becomes Cubism. Tricks from ancient astronomy + calculus becomes Fourier analysis. Bird watching + a need to engineer better clothes becomes down jackets. Creativity is

the art of synthesis - finding useful and/or interesting connections between previously unconnected things.

Now at this point you're probably feeling like this is a gross oversimplification - and you'd be right! For starters, before the insight can happen the tinder for the spark has to be present. There were plenty of artists around in Picasso's day but he was set apart both due to his exceptional technical fluency and his interest in African art. Then there's the fact that the stroke of insight doesn't come of its own accord - clearly there would've been many people aware of genetics, evolution, and the need for better optimizations - yet, in the end, only a handful of people came up with the idea for genetic algorithms. Then there's the process of sorting - many creative people note the fact that for every good idea you have there will be loads of poor ones, and distinguishing one from the other is no trivial matter [20]. Finally, it's a long way from that initial spark to real achievement - Fourier spent a long time formalizing and proving out his ideas before anyone took them seriously, and you can be sure that folks didn't just copy a whale's fin and stick it directly on a windmill turbine. Beyond the initial stroke of insight there are obviously other very important steps involved. Gather, Spark, Sort, Develop in no particular order (because creativity is a messy business) - these are the steps to creating something new.

However, for each of these steps, we can learn from those who've already achieved. We can note that for the cubists and the impressionists (who took key inspiration from Japanese prints [19]) their gathering stage was marked by exploring farther afield than most artists in their day. Einstein is often noted to have spent a lot of time performing thought experiments in his head in order to turn problems this way and thereby facilitate sparks of insight and inspiration. Isaac Asimov (a prolific science fiction author) noted the fact that sometimes it is best to be alone when evaluating and sorting through ideas because many of the initial ideas you'll have will be, in his words, "embarrassing" [20]. But these are just a few examples. In general, there are entire books written on this stuff. From Kaufman and Gregoire's *Wired to Create* [20] to Csikszentmihalyi's *Creativity* [5] there are loads of books out there chock full of lessons learned from studying what sets high achieving creative people apart.

In the light of the last section, all of this should be sounding tremendously familiar. We've got a specific goal - synthesis of previously disparate fields - as well as a whole lot of techniques, advice, and, may I say, mental representations from experts. In other words, while what comes out of the creative process is certainly novel, the process

of being creative is not novel at all! Synthesis is a skill,
with experts, that can be mastered itself! It's just a very
special skill in the fact that regardless of the field you find
yourself in, you're going to want to master this one as well
because creativity is how you adapt and push boundaries.
But as we've seen in the last section, mastering a skill is
no mystery rooted in talent alone - it is instead the result
of deliberate practice.

4.3   The Need for Organizations

Alright, at this point we know that the key to exceptional
skill and creativity is deliberate practice. However, we
also know that deliberate practice for even one skill takes
an extraordinary amount of time and, as we just pointed
out, one must invest time in practicing creativity too. Re-
member those violinists who'd spent 20 hours a week for
decades to master their craft? That was just for practicing
the standardized components. All in all, exceptionalism
comes at a very specific cost - and that cost is specializa-
tion. Each individual has only so much time and given the
massive investment required to master something, there
will only be a handful of things you can master in one life-
time.

However, as anyone knows, specialists cannot operate alone. People who operate in sales need things to sell. Musicians need bands or orchestras and places for those bands or orchestras to perform. Mathematicians only really become "useful" when engineers and scientists put their abstractions to use. A doctor is no good without the hospital staff and admin required to keep hospitals running. In short, specialists only become valuable in the coordinated presence of other specialists.

As a result, I, as an individual, will only be able to see benefits from my specialization if this coordination exists. And so we can see that creating high performers through deliberate practice is not enough. While it is definitely a necessary condition for taking full advantage of human potential, it is certainly not sufficient. What you also need are *organizations that can coordinate those specialists*. Put another way, without organizations, specialists are nigh useless. But this also means that organizations that do a poor job developing and/or coordinating those specialists are also useless.

I like the analogy of catalysts here. Within your cell float about loads of proteins, carbohydrates, salts, sugars, and all sorts of other useful, specialized, substances. However, on their own these chemicals just form a weird,

gooey soup because each of these substances on their own don't really do anything. What turns that soup into life are the catalysts that facilitate bringing the various substances together in useful and meaningful ways. This is what transforms a biochemical sludge into one of the most incredible machines in existence - the living cell. Organizations, then, are catalysts for human specialists. Without them there is no way to take full advantage of the human condition and as a consequence no way to tackle and solve our biggest problems or our most daring dreams. And so, if you wish to tackle something huge, if you to achieve in the highest order possible, you must do two things - first you must engender the most exceptional of specialists and then, with equal importance, you must build the organizations that will catalyze them. For without those organizations there will be no mechanism capable of mustering the human skill and energy required to shift a component of our world.

Chapter 5

The Value of Focus

The world is a really big place with a lot going on. No matter where you look, opportunity and problems abound. On just the matter of sustainability the United Nations has identified 17 separate goals each of which is enormous in scope - number 15 is just titled "Life on Land" [28]. Likewise the Millenium Ecosystem Assessment has identified 25 different ecosystem services, all with their own host of concerns [2]. And all you need to do is head over to your news feed of choice to get an overwhelming sense of all there is out there - economic recessions, public safety, the fate of democracy, crises in agriculture, issues with education... the list goes on and on.

Then there's the fact that the "Devil's in the Details". Take literally any of the above topics and you can subdivide it about a million times over to create thousands of different focuses, each with their own host of questions, issues, and jobs to get done. The world is so interesting and diverse that people can make a career out of studying a very specific people, at a very specific point in time, in an equally specific part of the world!

And then there's the fact that each of us is juggling so much in our day to day lives. There's school, families, friends, work, hobbies, commutes, cooking, cleaning, exercise... yet another overwhelming list.

All of this is enough to make one feel like there's not enough time to go around! So many world issues that it seems like one should care about, so many things to juggle in daily life, and then even just getting through the details of any one of these things can feel overwhelming. And then, invariably, there are those people who just seem to be doing it all without breaking a sweat. You know the ones I'm talking about - the ones who are part of the local government, while also holding a full time job, while also being involved with their local church, while going out every night with their friends, while also having kids, while

also... you get the idea. It leaves a person wondering what their secret is - how are they able to get everything out of life while the rest of seem to struggle with a far smaller TODO list?

Well, Clifford Nass - a professor at Stanford - wondered the same thing. So he brought together a group of researchers and a group of students to find out. He divided the students into high multi-taskers and low multi-taskers and then set about searching for what they specifically excelled at. But what he found surprised him - the high multi taskers just did worse at everything... Since then, lots of other research has followed this up and shown the same thing - there is no such thing as effective multitasking, the key to success is actually focus. [21]

To understand why this is requires that we look at several attributes of how our brains work (and don't work). Each of these examples on their own will make a great deal of obvious sense, but together will lead us to some pretty interesting conclusions about how to be effective as an individual. So let's dive in and start with the idea of attention residue.

5.1   Context Switching

We've all had that feeling - the one where you were just playing a game or watching a show and suddenly you're asked to direct your attention elsewhere, like toward homework or something like that. It's a nasty feeling and leaves one feeling frazzled and not totally focused. Well this is more than just a feeling. Sophie Leroy ran a study in which she gave a series of people some difficult puzzles to solve. Then, for some of them she would interrupt them and give them a new task. For for the others, she let them finish first. For those interrupted they performed worse - indicating that context switching in the middle of something isn't some kind of flip of a switch. Leroy named this phenomena - *attention residue.*

This attention residue can last for a really long time. Thanks to Bluma Zeigarnki's research we know that unfinished tasks at the end of the day can stick with you and continue interrupting your thoughts throughout the rest of your evening! This phenomena of leftover "background threads" is called the Zeigarnik effect [29] and getting rid of it requires taking the time to get your mind in a place where it feels like today's tasks are indeed done. Often times this involves planning out tomorrow in such a way that the tasks unfinished today have guaranteed space to-

morrow. And as you might expect this takes time to do.

But there's not just overhead involved in getting the last task out of your head, there's also overhead in bringing your faculties online for the next one. For anyone who's brainstormed or experienced writer's block, you know that it's really only once you get going that the going gets good - i.e. it takes time to warm up your brain to whatever you are doing. And getting to that warmed up state of mind can take quite a while. So, not only will you be taking time to get your mind off the last thing, but also taking to time to really get into the groove on the new one.

And let's be real, context switching is not fun. Having that distracted feeling, experiencing writers block, or feeling like you're really just not in the groove is not at all enjoyable. So both for efficacy and enjoyment's sake reducing overhead is the way to go.

This, of course, means making sure you've got large blocks of time to do things that are challenging. For example, suppose you have a 30 minute window open at work and you're tempted to try and get something done during that time. You're going to be spending several minutes pulling your brain of the last task, several minutes getting into the flow for the upcoming task, only to have a few

minutes left to actually do anything well. Which is going to leave even more open threads in your brain to distract you during your day! Definitely not worth doing.

Also note another conclusion that falls right out of this - multi tasking isn't real! We only ever really do one thing at a time, and every time we switch tasks we pay a heavy penalty in context switching. So we've got our first principle then - context switching takes a considerable amount of time and effort and represents a kind of overhead that should be minimized by instead working serially in large dedicated blocks of time.

To get at our next set of principles, we'll need to switch gears and consider the nature of willpower.

5.2   Willpower

There are quite a number of studies that demonstrate, rather nicely, that willpower is not only a resource used to redirect ourselves away from our default behavior, but that it is a limited resource at that. For example, in one study students were asked to memorize either a two or seven digit number after which they were presented with a choice to either have chocolate cake or fruit salad as a

snack. The minimal increase in cognitive load required memorize a seven digit number instead of a two digit one resulted in twice as many people taking the cake [21].

In another study, each participant started in a room with the researchers, a bowl of radishes, and a bowl of cookies. The researchers pretended like this was a study on taste and so instructed the participants to eat only a specific food while the researchers went off to do something else - for some it was cookies, and for others it was radishes. More than one radish assignee nearly ate a cookie! Then the researchers said they needed to pass some time to let the "sensory memory of the food fade" and gave each participant a puzzle to solve. However they neglected to tell the participants that the puzzle was actually impossible. At this point the researchers left and watched the students from behind a two way mirror. The cookie eaters worked for about 19 minutes before giving up. The radish eaters on the other hand only averaged 8 [9].

Likewise upon studying over a thousand parole board hearings, a clear pattern was found between the proportion of favorable decisions and how long ago the judges had taken a break. The default behavior for such judgment is to give a negative decision and the number of these steadily increased until break time after which the number of pos-

itive decisions suddenly jumped through the roof [21]!

The point of this is clear - willpower is a limited resource that eventually runs out and is therefore something we have to be careful to use wisely. So, two questions immediately - are there ways to increase the availability of this resource and how do we use it wisely?

5.2.1   Using Willpower Effectively

The answer to the latter question comes in two parts and both require a clear understanding of what willpower is - doing something that isn't your default behavior. As Charles Duhigg expands upon in great depth in his book "The Power of Habit" [9], our default behaviors are driven by habits. To understand this we must dive into what a habit is. To illustrate this Duhigg presents a very simple experiment that was done on rats. Specifically, rats were placed in a kind of "maze" that had chocolate at one end for the happy rat that could find it. When the rats were first introduced to this they would wander around largely at random and their mental activity would be quite high in the new environment. Eventually they would end up finding the chocolate and the researchers would repeat the whole thing. What was very interesting however was what happened as time went on. Eventually the rats would mas-

ter the maze and know exactly where to go and during this process of learning their brain activity went from very active to barely active at all and actually changed position in their brain - they had internalized the pattern and could now do it without much thinking. They'd moved the activity from the active decision making part of their brain to the default circuits in their brain.

However there was something another strange insight that came along with this discovery. While the brain activity during the maze walk decreased, the activity at the beginning and end did not. Specifically it seemed that the brain was looking for cues to start a default sequence, then fell into it, and then ramped again up again once the task was complete. This Cue, Routine, Reward loop turns out to be how habits always work [9] and is a model for how to embed things into your default behavior.

Two things come from this. The first is that the best way to use our willpower is to, instead of constantly fighting our default behaviors create habits in order to change our defaults to suit our needs. Indeed this has led to the observation by several people that no one is *really* disciplined, there are just those that exercise short bursts of discipline to change their default behavior in this way and those who try to fight their default behavior and eventu-

ally fall off the wagon. So when you see someone studying or practicing for hours on end, it's not because they are actively exerting willpower - it's that they've built habits that allow them to get into flow during those activities [21].

The second conclusion from this is that life has to be built around processes, not discreet tasks or goals. Habits are all about routines and therefore in order to build them you have to turn your life into a series of processes that you can repeat day after day in a largely consistent manner. This is quite a divergence from the kinds of chaos that life can regularly throw at you.

Which brings us to the second point on how to use willpower effectively. As Cal Newport exposes in his book "Deep Work" [29], distractions are the bane of productivity. Even if you're trying to establish flow, having your phone buzzing every two moments, or having coworkers popping over to talk to you at random, or having to constantly check email, leads to distractions that very quickly drain whatever willpower you have. So as just a common sense takeaway, it seems reasonable to divide your time into deep and shallow work so that you can group the distractions together and prevent them from draining your willpower. You can let your default circuit run rampant around messaging and communication at a different time

from your deep work - during those deep work times just create your own personal "work bunker" [29] in order to protect yourself from distractions.

In summary then, to use our willpower effectively we must organize our days and habits to create alignment between our default behaviors and what we want to get out of work while creating clear distinctions between deep and shallow work. In so doing we prevent our willpower from being drained unnecessarily.

5.2.2   How to Get More

Willpower often gets compared to a muscle - use to much and it gets tired. But the analogy goes further because like a muscle will power can be trained. Two researchers, Megan Oaten and Ken Cheng, did a series of experiments in which they got people to exercise their willpower in one arena (like going to the gym, or doing better money management, etc) and then showed that it created spontaneous changes in other parts of their lives (like eating better, smoking less, or becoming more productive at work) [9]. Exercise your willpower muscles and you strengthen them. But the reverse is also true - give into distractions frequently and your willpower wanes. Cliff Nass's research has shown that the brains of those who are chronic multi-

taskers or who are chronically distracted just remain over-
stimulated all the time and have trouble focusing even
when they want to [29]. In order to keep our willpower
muscle healthy we have to keep exercising it. So it's im-
portant to set aside time to focus deeply and practice using
willpower so that you can push your limits and stay strong.

Another useful note is that like a muscle, giving your
willpower rest gives it time to bounce back a little. In one
study two groups were asked to go on a walk before doing a
task requiring a lot of concentration. For one group, they
went for a walk in the woods, for the other they walked
through a busy city center where they had to dodge all
manner of people, cars, and the like. The group that went
on a lovely walk in the woods did significantly better on
the task than those who'd been busy trying to make their
way through the city center. The lead author Marc Berd-
man attributes this to the fact that while walking through
the woods we no longer direct our attention, whereas in
the city center we have to be on guard and so are sapping
our willpower as we go about. Taking time to be idle gives
us an opportunity to replenish a little bit [29].

Now one note we should make before coming to any
conclusions about "unlimited power" is that like any other
muscle there's not only diminishing returns to any of these

techniques but there are also limits. For example, in his studies on expert performers Anders Ericsson rarely found people who's time spent truly focused on difficult *new* tasks ever exceeded 4 hours [29]. So while there are certainly ways to extend the time you can spend draining willpower, be sensitive to your limits. Work beyond that time will, by definition, not be the best you can do.

5.2.3   When the Tap Runs Out

So what to do when your willpower tap runs out and you find yourself struggling to focus or realize you are operating suboptimally due to mental fatigue? Embracing idleness can be extremely powerful. People have run studies that show that sleep (or even naps) can allow your subconscious to solve problems that you'd been struggling with all day [20] or that going for a walk or using some other way to get your mind off things will suddenly give you that eureka moment that you've been looking for [29]. In general studies have found that your subconscious faculties are very powerful on their own and often times better suited to certain kinds of problem solving. So taking a break doesn't actually mean you've stopped thinking or being creative - it just means you've let a different part of your mind come into play. And from this vantage point it's just plain dumb to burn yourself out working subopti-

mally when a nice rest and good night's sleep would mean you'll have meaningful breakthroughs you can follow up on with your full faculties the next day.

When the tap runs out, and perhaps even before then, *rest*.

5.2.4   Use Willpower Wisely

All in all then, we've learned a couple of things about using willpower wisely:

1. Divide your deep and shallow work intentionally, no point draining your willpower unnecessarily

2. Use willpower to create habits not to fight yourself day in and day out

3. Exercise your willpower to keep it strong (i.e. work in large blocks of focused concentration)

4. Take breaks when you feel yourself getting tired

5. Embrace idleness and don't overwork yourself

One final note is that willpower is not just for work. It's for anything you really deeply care about and want to give your all. So friends, family, hobbies - they will

all need willpower too. Which points out something big
- even if you had 10 hours of deep work in you everday,
with habits and the benefits of practice involved, you only
really have 5 or so hours to dedicate to work each day.
And as anyone who's worked on tough problems knows -
five hours quickly seems like very little. Unless that is, you
have *focus*. If you can dedicate that attention to one or
two things, fine. Anything more than that and you'll just
perpetually feel like you aren't doing enough. So, once
again we come to the conclusion that being effective re-
quires focus. Multitasking just spreads you thin.

But enough of that, onto the growth mindset!

5.3   The Growth Mindset

We often make decisions on the basis of what's happening
in there here and now which... makes sense. The here
and now is what we can feel and the future is not a given,
so this, current moment is certainly of far greater impor-
tance than any single moment to come. The problem in
this calculus is that we often forget that while each coming
moment may have less valuable than the present, there are
way more future moments. So thinking about how to build
upon all of that time-to-come is one of the best places to

find ways of being ever more effective.

The first and most obvious of these "growth mindset" strategies is education. Everything you can do today is thanks to what you learned yesterday, and so what you learn today will make you better tomorrow. If, once out of school, you just stopped learning and worked as hard as you could you'll seem extremely productive in the short term, but in the long term you'll get outpaced by the version of yourself that decided to dedicate time to education as well. However the reverse is also true, a version of yourself that never ever starts working but just learns gets even less far. So, a balance is necessary. Continuing education is one of the best ways to ensure you just get more and more effective over the long run.

Then there is what Keller refers to as the "domino effect" [21]. I find the best way to illustrate this (given what a long play it is) is to refer to one of my favorite kinds of game - simulated city/civilization building. In these games you normally start out with very, very few resources and people. For example, in one of my favorites as a child you start out with a few huts on the Nile river. At this point in the game your options are quite limited - instead of building pyramids, you're organizing farmland, building new huts, and getting cleaner water sources. But

as your people get healthier and their work more efficient, a surplus appears and you can start to use that to create healers, roads, and wagons. This in turn provides for even more surplus which allows you to take even larger actions, which creates more surplus, which generates more action, which... you get the idea. Before you know it you've started construction on your first pyramid. This kind of exponential growth comes when each new increment of work we do both takes advantage of what we've already done, and sets us up to be more efficient in the future. We get buoyed by our own past doings! The reason why Keller refers to this as the domino effect is because a falling domino can knock down another domino that's a fixed multiple of its size. So for example if that multiple is 1.5x then if your first domino is an inch tall, the next domino can be an inch and a half, the one after that 2 and a quarter inches, then 3 and a third, then 5 inches and by the time we get to the tenth domino it is roughly 5 feet tall! Compound growth is an exceptionally powerful thing but it requires that you are in fact compounding something on itself. If instead you just redirect your energy in a different direction from one moment to the next, no compounding is going to happen.

Now when it comes to getting that compound interest to have a quicker return it's wise to remember the Pareto

principle (also known as the 80-20 rule). The idea here
is that for any effect, 80% of it is likely the result of only
20% of the underlying causes. The classic example of this
(and the one that led to Pareto coming up with this prin-
ciple) is wealth. A small fraction of people control the
majority of the world's wealth. In Pareto's day it was
roughly 80-20. But as it turns out this rule applies pretty
much everywhere. I've come across it while teaching peo-
ple, building software, or even while trying to get a recipe
to work just right - a minimal amount of causes creates the
most impact. Another way of looking at this is in terms of
diminishing returns. Everyone knows that the more you
try to optimize something, the harder and harder it is to
make it better. Learning how to go from making a sauce
so awful that no one wants to eat it to something palat-
able - relatively easy. Making a sauce that just comes out
above the best in the world? Really, really hard. Minority
of causes, majority of results.

    This principle is very useful because it also means that
if we take the time to figure out what that hypothetical
20% is, we can save ourselves a lot of time - we can get
to knocking over that next domino that much faster. If
instead we don't take the time, chances are we'll end up
dipping quite deeply in the 80% of causes that create only
20% of the impact - which definitely doesn't help us work

more efficiently. Here then is our third and final principle of this group - take the time to figure out the "keystone" causes of whatever it is you're doing so that you can spend less time working and get just as much result.

So what's in common between education, the domino effect, and using Pareto's principle to our advantage? It's the fact that if all you cared about was the present, you'd never invest time in any one of these! Education takes away time from high priority work that you might be stressing about. The domino effect requires that you stay focused on building on what you've already done even when your boss turns around and tells you there's something higher priority but relatively unrelated that needs to get dealt with urgently. And to find that golden 20% requires once again taking time away from work to deeply understand what it is you're doing and what its keystone causes are. For those who apply those principles they will *always* look less productive than their peers in the moment.

However, over time they get to reap the rewards of compound interest! And this means that their base level of productivity grows exponentially. So while they may look unproductive in comparison to their present-focused peers in one moment, a few years down the line the two won't

even be comparable. *Investing* your time is the most important thing you can do to make yourself more productive - everything else we've talked about pales in comparison because this stuff *raises the baseline.*

However, as we mentioned before, compound interest only works if you are actually compounding on the same thing. All of these strategies require that you have focus, and focus that you can maintain over *years.* So far we've noted the importance of depth and focus in work, but here we're talking about depth and focus that remains consistent over long periods of time. Yet, without finding that focus we'll never be able to take conscious, deliberate advantage of compound interest on our own capabilities.

5.4   People, then Problems

The first thing that should be clear from everything we've said thus far, is that multitasking, for the sake of multitasking, is not a virtue. It creates more overhead, it reduces our willpower, prevents us from educating ourselves as deeply or consistently, interrupts the compounding of our own work, and in general just takes the potential we have and smears it out so that we become a kind of "master of none" [21]. Focus is good, and for making real progress,

focus is necessary.

However when we look at the fact that the whole point of our "compound interest" is to take us beyond what we can perceive or imagine today, it also becomes clear that our focus is not just about the goals of today - instead it has to encompass our growth over many years to come. How on earth can we find focus that will extend past what we know today? Well, imagine once again that we're playing the civilization building game. At no point are our goals fixed, instead what we are doing each and every moment is monitoring what we have, what's been working well, and how we can take advantage of it to launch ourselves forward. In other words we're not so much focusing on a specific outcome but on understanding what is driving our success today and how we can continue to grow *that*.

Similarly when it comes to our considerations of willpower we found that the key is to use our discipline not to fight our default behaviors but to rather use that discipline to engineer and redirect our default behaviors through the formation of habits. But as we've seen, habits are rituals, processes, ways of life. And so once again we see a need to look for common, repeatable patterns in our lives that we can turn into habits.

In other words as we go about our work, the key to
our long term success is in finding this unifying frame-
work around which we can build habits and upon which
we can keep compounding our efforts. We are not just a
bag of skills but a moving, developing centroid of processes,
skills, resources, connections, capabilities, ideas, and per-
spectives that have been honed over time.

Why does this matter? In our wildly varied and often-
times overwhelming world we typically take the problems
or opportunities out there and try to figure out how to fit
ourselves to them. You see this all over the place. Charita-
ble operations ask "what can you do?". Your work hands
you jobs and expects you to be resourceful enough to fig-
ure out how to get it done. We ourselves orient around far
off dreams that more often than not have very little to do
with who we are today. We see the world as a collection of
aspirations, and success as our ability to conform to those
things.

However now that we know what creates success in the
individual, it should be clear that this whole mentality
should be flipped upon its head. Success comes not from
launching ourselves into whatever problem is at hand but
instead in looking for the things that we are best equipped

to do, and especially those things that will allow us to build upon and develop ourselves even further. It's not about finding the most important problem you but finding the problem you can be most important to. And to be important to that problem you must prevent yourself from being diluted by the world in the process.

So, to bring this back to the beginning - yes, the world is overwhelming and often times frightening, but it is not your responsibility to be involved with it all. The best you can do with the time and energy you've got is to follow the part of the adventure well suited to you and devote your heart and soul to it.

The problem now is, if rather than being able to specify what needs doing and driving people towards those tasks, each person is just taking up the things best suited to them, how do we ensure the work that needs doing still gets done? This, is a challenge to organizational development theory.

Chapter 6

Cheap Failure

In the summer prior to my senior year at college I got an internship with a satellite communications company where I, and two fellow interns, attempted to build some machine learning models. I ended up getting hired full time and spent the next two and half years working with that group. They were the best engineers I'd ever worked with and I still attribute a lot of my personal success to what I learned and absorbed being around all of them. However I eventually ended up leaving for greener pastures specifically because the project we were working on just never seemed to really go anywhere. Indeed shortly after my departure the group re-branded, switched tactics, and more

or less left the work we were doing behind.

I think during college (and even before that) I had this notion that if you had the skills and the time to use them - success was just around the corner. Yet here I was having worked with some of the best engineers I've known, for years, and we'd more or less gotten nowhere. For a young professional it was a moment of existential anxiety but as I thought about it more I started realizing how naive I had been.

If skill was all that was needed, companies would never fail. Yahoo had incredible talent, yet it was taken down by Google. At the time of writing Google is failing to step up to the Artificial Intelligence plate in its tossle with OpenAI and Microsoft, even though the underlying technology (transfomers) was created at Google! Facebook still attracts some of the best talent in the world and yet that business seems to be going down the tube quite quickly. Skill and masterful execution are necessary but not sufficient conditions for success. And so I began wondering what other conditions were missing.

In the course of my reading and subsequent experience I've come to the following conclusion - the key to success is making failure as cheap as possible. The reason for this

is that failure is inevitable, curve-balls will come your way, things you thought you knew well will surprise you, and so failure, over time, just becomes a familiar face. However, failure itself, doesn't mean the end of success, so long as you can pick yourself up, learn your lesson, and move on, you'll eventually make it. The problem comes when failure dashes you to the ground in such a way that you can't get back up - maybe you're out of resources, maybe you're not reading the writing on the wall, maybe you've eroded the trust of those you're working with - it's the magnitude of the consequences, not the failure itself that's the problem. So to find success, make failure cheap.

The easiest way to do this is to recognize that imagination is cheap [24]. If you discover a mistake in a design that's in your brain, you can just go right ahead and fix the problem - mental mistakes just cost time. So the more you can work things out with pen and paper, the less likely you're going to make the mistake in the real world and suddenly have money, resources, trust, and the like at risk. Proper (and thorough) design thinking is the easiest and most convenient way of making failure cheap. However it doesn't cover everything.

Your brain and the physical world are two distinct things and while you can get them into pretty close align-

ment, the fact of the matter is that there's no proof like
the pudding. You can only answer questions in your brain
that you know you need to ask - however there are a whole
suite of questions that you simply won't realize exist. The
answers to these questions are unknown unknowns and the
only way you find out about them is by making mistakes in
the real, physical world where consequences can be nasty.
Therefore figuring out how to find these kinds of things
early (and thereby minimize their overall impact) is also
super important - we'll call this line of "failure cost reduc-
tion" iterative execution.

In my experience these two strategies - iterative execu-
tion and design thinking - *are* how to make failure cheap.
So, if we want to understand how to turn our skills into
success we'll need to dive into each of these in turn. Let's
begin with design thinking.

6.1   Think in Systems

It is one of the supreme pleasures of childhood to build
castles in the sand. Why they are called castles, I don't
really know, given they always morphed into sand-holes
or sand-mountains but it was nonetheless such a joy to be
out on the beach with a bucket and shovel in hand and

reshaping the topography.

However, it was always a bitter sweet ordeal because one knew that within a few hours all evidence of your toil would be wiped away. The topography of the beach was not controlled by you but by forces of waves, wind, and water. The grand processes of the natural world have the final say.

Life, in many ways, is no different. The politicians you vote for, the prices of the food you buy, the nature of the education you receive are all the results of underlying systems and processes. And so, when we go about trying to make a difference in the world (and reducing the cost of any failure along the way) it's important to we make sure we don't end up building castles in the sand.

We have a tendency, as a species, to gravitate toward dealing with symptoms. Angry masses depose their leaders without changing the underlying corrupt system. Students cram for tests again and again instead of altering their long term study habits. Doctors prescribe all manners of medicine without a lot of focus on the behaviors that led to the issues in the first place. But if we want to be able to create lasting, consistent change we must move beyond this sand castle building - we must look to

the underlying systems that led to where we are and make
changes to them. We must think in terms of systems.

A great place to start understanding how to do so
is Meadows' book "Thinking in Systems" [26]. While it
would be impossible for me to recap everything in that
book, there is one very important conclusion that I wish
to highlight here. In a similar vein to our "symptoms first
thinking" we also have a tendency to try and blame the
ills of the world on poor thinking or just straight up evil.
As a result it seems like an obvious conclusion that if we
could just put better people in the right places all would
be well. Yet as Meadows points out, once you start un-
derstanding the non-linearity that is inherent in systems it
becomes clear that perfectly rational, well meaning, good
people can, together in a system, generate some pretty aw-
ful and seemingly irrational behaviors.

As an example let's take a case out of Meadows' sys-
tems zoo - a car dealer [26]. In this situation the car dealer
has two interactions - one with the customers and one
with the car manufacturers. However, while this situa-
tion seems only trivially complicated, it quickly illustrates
what can go wrong with systems. What's important in
this example is that the car dealer is having to balance
out how quickly she buys cars from the manufacturer with

how quickly she sells them.

Now in this example, as with the real world, there are delays involved. It takes time to place the orders to the car manufacturer and it takes time to get a good sense of how customer behavior has changed. As Meadows demonstrates, these kinds of delays result in oscillations in the stock of cars at the dealership at anytime. Basically, what happens is that if sales increases slightly, given it takes time to notice the shift a drop in inventory will result. This drop in inventory ends up pushing the car dealer to put in a large order to the manufacturer. However because this order needs to compensate not only for the loss in inventory but also the increased rate of sales at some point the inventory overshoots the sales alone. But it takes time to correct this with the manufacturer and by that point the dealer will be trying to correct downward to deal with the excess of stock. This then brings us back to a lack of stock and the cycle continues.

This however is where things get interesting. The obvious thing to do here is to remove the delays as they seem to be the source of the problem. However there is really only one delay the car dealer has any control over - her own response time to customer sales. But as Meadows demonstrates by actually simulating what happens with

a shorted delay, the oscillations only get worse! More or less the quicker response also results in more dramatic and therefore over-compensatory responses. As it turns out the way to dampen the oscillations is not to reduce the perception delay but to increase it so that it better matches the delay from the car manufacturer.

So even in a single system with one actor and two interactions, that person can take the action that seems like the obvious good solution and just make things far worse! Our dealer was having issues due to delays but it turned out that the solution was actually making one of the delays longer! Rational actors in complex systems do not necessarily produce rational results.

What to make of all of this? Well remember that, you yourself are one of the rational actors in this system and so you too can make the very same mistake our car dealer did. Indeed the only way to avoid their mistake is to recognize and understand the non-linearity present in the system and come up with solutions cognizant of that. So we've yet another reason why systems thinking is exceptionally important to improving our chances of success.

But there's another lesson here, and one that becomes apparent when we think about how multi-agent systems

select for certain kinds of behavior or people - even when those systems have the best of intentions.

The most obvious example of this is the political system in the United States. Politicians here are reelected every few years. This makes good sense if you're trying to provide a quick feedback opportunity for your voters. However it also leads to politics that has a hard time dealing with long term issues as politicians are motivated by their immediate next upcoming election. Another example comes from the financial world. Given the risk involved in lending money, it only makes sense to receive some kind of return on investment. Yet this results in a self reinforcing feedback loop that inexorably drives money into fewer and fewer hands. The principle here is clear, systems with feedback loops (which as Meadows points out is pretty much all systems) have the effect of actually changing or selecting for the behavior of the actors!

So rather than playing the blame game and wishing for better people or better behavior a more constructive approach is to figure out what needs to be added to the system to select for the kinds of behavior *that would be helpful.* Like with our sandcastles analogy we are thereby changing what leads to behavior instead of trying to patch the current behavior (just to have it wiped out again in

the future).

All in all then it should be apparent how important it is to think about things in systems and specifically what thinking in systems really means:

1. Looking to change the sources not the symptoms

2. Recognizing the importance of non-linearities

3. Understanding that the behavior of actors is a property of the system itself

To make real lasting change we have to look beyond the symptoms and into the wild, non-linear systems underlying the change we want. In other words we should ensure that when we are designing, we understand the underlying system and that we are designing updates to that system.

6.2   Be Scientific

At the basis of all the designing, executing, and, frankly, imagining that you'll be doing is an underlying model of the world sitting in the brains belonging to yourself and those you end up working with. When you make assertions

about how things work, what value you can provide, the systems you integrate with, and so on all of this is founded upon what you know about the world - or rather what you *think* you know.

Two issues face us here - comprehension and truthfulness. Gaps in our knowledge act more or less as blind spots that we can either resolve before we get to deep into the work or later when we suddenly realize there was something we didn't even think to think about. But even worse is basing decisions on knowledge we think we have but which is actually inaccurate. So one of the primary focuses of our "design process" has to be acquiring and testing relevant knowledge which brings us right into the realm of philosophy because we must begin with the question - how do we determine "truthfullness" in the first place.

6.2.1 Truthiness

Any introduction to logic and critical thinking will point out two ways of reasoning about the world - deduction and induction. Deduction, from a logical thinking standpoint, is definitely the nicer of the two. Deduction entails taking a series of premises (which you hold to be true) and then using formal logic to create a proof of some conclu-

sion. What's nice about deduction is the fact that it leads
to conclusions that are not likely or probably, but abso-
lutely and fundamentally true - given your premises are
correct. And that's the Achilles heel of deduction - it is ab-
solutely dependent on the premises being true themselves.
Likewise, deduction cannot create its own premises be-
cause that would just require a series of different premises
whose truth would then be in question. This is why an-
cient Greek philosophers made such a stink about "self
evident" premises - premises so obvious they don't require
proof.

At first this seems like a reasonable way out. For ex-
ample Euclid proposed a set of very basic premises (like
"things which are equal to each the same thing are also
equal to one another") and came up with the geometry
you use in high school and for thousands of years was
considered *the* geometry of our world. And yet, thanks
to Einstein and Riemann we now know that some of his
self evident premises are not actually true at all. Deduc-
tion can show things follow from their premises, but it can
never show that something is truthfully real.

Alright, so what about induction? Induction is what's
behind the fact that you believe the sun will rise again
tomorrow. The basis of induction is the assumption that

given seeing a pattern many times, it's likely you'll see that pattern continue into the future. Seems pretty reasonable, right? Unfortunately, as many philosophers have pointed out (with Hume being the most notable) induction can in no way *prove* anything [23].

The first reason for this is that there's no proof for induction that isn't itself an inductive argument [23]. And circular arguments are no good. For example suppose I assumed the opposite of induction as an argument - i.e. that if I observe a pattern I expect it to not work out the same way the next time. Then the fact that so far the pattern of normal induction has held I'm allowed to believe that in the future my twisted (radical) version of induction will hold. Circular arguments let you prove pretty much anything, so the fact that there's no argument for induction that isn't itself circular doesn't bode well.

However we could suggest that maybe we just take induction at face value and use it without trying to build any kind of proof. Couldn't it still be useful? The problem is that induction at face value is demonstrably very dangerous. A classic example uses the notion of a contrapositive. In formal logic if I have the statement - all ravens are black - the contrapositive statement - all things that aren't black aren't ravens - is taken as logically equivalent.

In other words if I can prove the latter I prove the former. However from the point of view of an inductive argument all I need to do is go outside and collect green leaves to gather evidence that non-black things aren't ravens [23]. Obviously there's more to evidenced based thinking than just straight induction.

Alright so we clearly need something else. So what's the right way of creating arguments that can allow us to prove things? Loads of philosophical and mathematical literature will quickly convince you that the answer is - no one knows for sure [23] [22]. However we can't throw up our hands because we need to get at the truth or something like it somehow! So what are we to do? Well we can take a leaf out of our own book. Remember with design thinking we aren't trying to avoid failure altogether, just reduce its impact. Similarly here rather than pursuing truth we could look instead to reducing error. Put another way, what if instead of trying to prove our mental model right, we tried to look for how it's wrong. Then every time someone proved someone else wrong is an example for us to follow! So let's take a look at how we might do this.

6.2.2 Stress Testing

The first problem we come across when thinking about stress testing our model is figuring out what our model actually is. For most of us we make assertions automatically using the mental models that have become embedded in our subconscious. This is useful because our subconscious is very powerful [29] but it also means it can be pretty unclear what's actually happening behind the scenes. Thankfully there's a pretty straight forward way to start teasing out the details of our mental models - making predictions.

More or less the idea is this, for some particular subject or event that you want some certainty around, start by thinking of all the measurables you could create from it. In doing this it is extremely helpful to look for ways others have measured or represented data in the past to get ideas for all the kinds of observations you could make. For example if we're talking about the physics of the sky, weather, temperature, color, consistency, wind speed, etc. could all be measureables. More or less start by being very *observant*. The more ways you look at the data the higher the odds you find illuminating surprises. But surprises only occur when you yourself have *expectations*. So in each of these cases come up with what you think each of these should be like and why - i.e. come up with spe-

cific predictions that you feel very confident about. One
of three things will happen at this point:

1. Your expectation and reality line up

2. You realize you don't have any expectations

3. Your expectation and reality don't line up

In the first case there's nothing to. In the second it
means you've found a spot where your mental model is
lacking comprehension (it's up to you to determine if that
lack of comprehension matters). And in the third case it
means that you've found an error in your mental model
that needs to be dealt with. In general though, through
this observant, fact-foil [23] approach you'll quickly find
the boundaries and specifics of your current mental model
as well as any obvious errors.

It's worth noting here how empirical you have to be-
come for all of this to be possible. You must have some
basis to make predictions and to test them you need to
run experiments and actually collect data. So if you find
yourself in a position where you realize you have no data
behind the assumptions you're running on something is
clearly wrong.

Now, at some point you may find that your mental model and what you're observing line up pretty well. At this point (and honestly before it) you can deploy another mechanism for rooting out errors - learning from the mistakes of others. This too is a straight forward process, all you need to do is find folks who've been making predictions like your own and see where it is they've been found to go wrong. Then push your model into those areas as well and see how you fare. So for example if you're running surveys it's good to know the various kinds of survey bias that others have run into in the past.

And speaking of learning from others it's just as important to seek alternate perspectives to your own. We usually do this when we're learning about something for the first time and are trying to absorb a matured perspective, but even as we become experts, finding ways in which people are thinking differently from us opens the doors to understanding where our models might be wrong (or not comprehensive enough). In general, like with the fact-foil, a compare and contrast approach is usually extremely productive.

An important point when looking for the perspectives of others it to look for mental models that have clear internal mechanisms. The easiest way to illustrate what I

mean by this comes from an example in cooking. If you
open any odd cookbook you will likely find recipes telling
you how to, say, pan fry chicken. However many recipes
tell you how this works from a "steps" approach - do X get
Y. This is fine until you do X and get something that isn't
Y at which point you're totally lost. However if you find
a recipes that explains the *mechanisms* of what's going on
(for example why brining chicken helps prevent drying out
the meat or why oil helps create a crispy skin) then you
have the knowledge to *modify* the steps to meet your spe-
cific conditions.

In general understanding *why* something is the way it
is is far more valuable than simply just knowing *that* it is
a certain way - it allows you to see where things could go
wrong, fix issues that do arise, and in general just gives
you a much deeper and more thorough understanding. So
when you're building mental models and learning the mod-
els of others, search for the mechanisms (or physics) of how
it all works and why.

Finally it's important to avoid the most (in my mind)
nefarious error in model building - over fitting. Over fitting
occurs when you build a model that can explain everything
you've already seen but has no predictive power. In gen-
eral given the flexibility in model building you always have

enough freedom to build some rube-goldberg machine that through its sheer complexity is able to capture every bit of variance you've found so far. However these are not useful models because they never let us predict anything new (and therefore rarely if ever line up with the truth). To protect yourself from this its important that every time you make modifications to your model you have plans on how to test the modifications on something new, otherwise you'll always have success in modifying your model but no success in using it in the future.

There are obviously loads more tips and tricks you can use to seek out and destroy errors in your thinking but between these four - observant fact-foil, learning from the mistakes of others, seeking alternate perspectives, and avoiding over fitting - I suspect you'll naturally come across the others. Indeed the combination of these four, and the fact that the specifically drive exploration and expansion of your mental models means that they also drive comprehension - which was the other quality of knowledge we were seeking out at the beginning of this section. Removing error and comprehension typically go hand in hand.

6.2.3   Summing it Up

In summary then to get our knowledge into shape and make sure it's comprehensive enough we should actively search for and root out the errors in our ways of thinking. This however is a very unnatural thing to do - indeed one might say that constantly just looking for where you're wrong could get pretty depressing. As such it's extremely important to the success of this kind of whack-a-mole that you develop a mindset where finding and resolving new errors is rewarding and fun, otherwise you'll eventually just lose patience and move onto something else. This is also the kind of exercise that can quickly get extremely overwhelming - so make a habit of documenting things clearly and just in general writing down and organizing what you find - otherwise you'll quickly feel like you're losing your mind. But, if you are able to setup consistent habits that work to drive out the errors in your thinking then you'll find yourself day by day more confident in what you know and the boundaries of that knowledge.

6.3   Create Together

Alright, so you've got a grand idea. Maybe you've got a notion for some social good you can provide, maybe you've got an idea for an awesome app, or maybe you just want

to provide a really neat and novel experience. Regardless you've got a value proposition and a set of people who you think stand to benefit [12].

Now if you're like me (and most people I've bumped into and read about [33]) your natural inclination will be to assume that this brilliant idea you have is rock solid and anyone with half a brain would recognize just how cool it is too. However, as you might expect at this point, life is never so simple.

For example the idea behind Zambia Feeds [24] was to provide low cost chicken feed in order to kick start a market a small scale poultry farmers thereby providing competition to the incumbent (and indifferent poultry providers) and also provide a means of living for many subsistence farmers. Seems simple - provide the feed at a low, create an industry. However upon thinking about how this would work from the beneficiary's perspective it became clear that there were a *lot* of other things that had to fall into place for the cheaper feed to even matter! People needed education on how to raise chickens, needed to know where to purchase chicks, had to be able to construct the appropriate fencing and hen houses, needed vaccination services for the animals, and so on. Without all of these things the value add just didn't matter because the value

was couched in addition required context.

Beyond just additional context there's also the matter
of what *specifically* creates value in the beneficiary's mind.
For example when people first started trying to market
toothpaste, they found that the health benefits alone were
enough to do the trick [9]. People knew, in theory, that it
was good for their dental health and yet they just wouldn't
really latch on. Instead what really launched toothpaste
was the tingling feeling you get from specific oils compa-
nies add to it. Turns out that people need a sign that
their mouth is clean to build the habits that have made
toothpaste such a central part of our culture now.

And then of course, sometimes the value proposition
can just be dead wrong. I myself have personal experience
with this - building things that in the end no one ends up
wanting but I was dead convinced was going to be the best
thing since sliced bread.

The point of all of this is that developing a value propo-
sition is not straight forward and one needs to work with
and develop a deep shared understanding with your users
or beneficiaries to know you're really on the right track
and have all your ducks in a row.

But users are not the only people you'll be working with during this whole process. Once you know you want to build you'll almost certainly be working with other people to make it happen. I'm talking about vendors, sales folks, developers, and so on. And there's a lot of potential for miscommunication here too.

A classic example is the failure of "requirements" [33]. In his book "User Story Mapping, Patton talks about the fact that sending requirements around through mediums like email or slack is a lot like playing telephone - each person listens, interprets it their own way, and then sends on what they thought they heard so that the end result is something bearing almost no resemblance to the original directive. But, as Patton also points out, even if the requirements got through unscathed by this grown up version of telephone, they rarely do the trick because any document that we create is incomplete. He likens it to a picture you took on a vacation. Look at it yourself and you see so much context, such great times, so many stories. When someone else looks at it, they just see a nice picture with some people smiling in it. To get everyone on the same page requires actively pursuing shared understanding, not just passing on requirements [33].

Another problem that can arise, beyond just building

something besides what was asked for, is building the right thing and then realizing it's not what you wanted at all. For example you might find that things end up being more costly or more complicated that you expected. Or perhaps you end up asking for something that's nigh impossible and therefore delicate and hard to maintain. A conversation with your developers would quickly elucidate these kinds of things, as they have a better understanding of the costs and feasibility of the details than you will. Yet again a place to build shared understanding.

Okay, so you've got a value prop and you've got a way to build it. But with what money? How will you keep it running and make it sustainable in the long run (assuming that's a goal of course)? This brings us to our third group - the folks who pay for it. Rarely are these people and your beneficiaries the same - even if you're selling something directly it's likely that you also care about folks like shareholders and other investors. If you're working towards some social good it's like you're being funded by groups like the local government, NGO's, charities, or some combination thereof. And many applications end up making most of their money through side channels that fall out of their main value proposition. Google, a search engine, makes their money through the advertising they can do while you're searching the web (and they're extremely

good at it 'cause they know what you've been looking at).

It should go without saying that blindly plotting a path forward without figuring out what's going to be required to keep the lights on is a bad idea. And so here is yet another group with whom you'll need to build shared understanding [24].

Given these examples it should be apparent now that part of building this shared understanding is taking advantage of the expertise of those you'll be working with. Your users are the best source of information on what is valuable to them and what fits into their lives, your developers best understand the details of how to get things done, and your investors and benefactors know best how to navigate the politics and keep your value proposition up and running. So it should come as no surprise that our fourth group of people are those who've built things like what you're trying to build before. What better place to get wisdom and to avoid silly mistakes than to team up with people who've already run the gamut [24]! It's always best to stand on the shoulders of giants.

In sum then we've seen that we have four groups of people that we need to be building shared understanding with:

1. The beneficiaries - those who receive the value

2. The developers - those who build and run the value

3. The benefactors - those who resource the value

4. The advisers - those who's been in your shoes before

Each of these groups hold the expertise and knowledge to flesh out, refine, test, and create a different facet of your idea and without all of them you won't get a complete picture. So now the obvious question is - how does one create shared understanding?

6.3.1   Shared Understanding

There are a *lot* of books on this subject. Patton's book [33], Value Proposition Design [12], and the Social Entrepreneur's Playbook [24] are just a few examples. Part of the reason there are so many different resources out there is that the specific tips and tricks depend on what you are building shared understanding around and with whom. So I'm certainly not going to try to get into all that depth here. However, I have found in my reading, practicing, and thinking that there are a few general themes that are certainly worth mentioning and run across the board:

1. Don't just talk, document

2. Be precise

3. Be relevant

4. Create together

The first - don't just talk, document - gets to the idea that it's very easy to hold a conversation with someone and never actually end up talking about the same thing. It's only once you start drawing out the details, writing definitions down, seeing the whole for its parts, and just generally getting past the five or six things you can hold in short term memory at once [11] that you start to see the differences between your understanding of things and someone else's. Furthermore as you go between different groups and try to create shared understanding around the same thing in different contexts you don't just want to depend on your memory otherwise you'll just end up playing telephone, like we mentioned before. Documents (with lots of illustrations and definitions) are how we can capture, record, and refine our present understanding of things with others. However, make sure you don't fall into the requirements trap - documents are only complete to those who've developed a shared understanding around them through actively brainstorming and conversing - they are never a complete form of communication unto themselves [33].

The second principle - be precise - digs into these ideas further. The devils are in the details and you'll never find them if you don't get into those details. So find ways of being as precise as you can (without becoming inaccurate) when having conversations with others so that you can sort out not just the big picture with them, but the details as well. It's the difference between asking someone if they see the same bird and whether they see the same robin - in the first case you might both agree you're looking at the same bird when one of you is looking at a crow.

Being precise is great, but it can also lead to unnecessary work if you're not asking questions relevant to person you're talking to. Remember each person brings a specific kind of perspective and expertise and that's what you want to tap into. You don't want to ask your users how NGO funding works (unless your user is the NGO) and you don't want to ask your investors how to setup a database. Think carefully about what perspective a specific conversation will bring and stay focused on that.

Finally, building shared understanding is a *two way street*. You should not just be passing off requirements to developers. You should not just be taking requirements from benefactors. And you certainly shouldn't just be forcing a "value proposition" down users' throats. Every one

of these interactions should be collaborative and take advantage of all the creativity, passion, energy, and expertise available in each context. In other words you should be *creating with* everyone you come in contact with. You and your developers should come up with the designs and implementations *together*. You and your beneficiaries should develop the value proposition *together*. You and your benefactors should develop a business plan *together*. And this should be happening right from the start, don't wait until you have a polished version of things to bring your ideas forward and realize you have no idea what you're talking about. Create together, period.

So in sum, document like crazy, be precise and relevant, and if you ever find yourself doing things alone, stop, go find the folks you should be working with, and create together and in so doing you'll ensure that what you build not only take advantage of far more expertise than you yourself possess but will actually matter to folks beyond yourself (which is the goal isn't it?).

6.4   Be an Artist

At this point if you've gone and start creating questions around you mental models, started roughing out the sys-

tems that you'll be interacting with, hit the books and found questions to help drive precise, shared understanding, and just generally started listing out the questions you need to answer and the things you need to create and design you'll have a list that is entirely overwhelming (and if you don't something's wrong). So, just as important as asking all of these questions is understanding how to prioritize and organize the work. And for that we'll pull a leaf out of the artist's book [33].

If you've ever watched someone draw a portrait, you'll know it happens in steps. First the artist will start by drawing ovals and rectangles and squares just to outline and orient basic things like the position of the face and any general background features. Maybe there'll be some lines thrown in to indicate the middle of the face or where the eyes are, but at this point whoever is drawing is just trying to orient things and make sure proportions are correct. If they find something they don't like with a quick use of their eraser they can get rid of the offending line and redraw it as they like.

Once orientations are looking good they'll move onto using simple shapes once again to start placing eyes, ears, the nose, mouth, etc. At this point all of these things are still unrecognizable but for their positions - blocks and

ovals and triangles are still all that's in play. But once again this allows for simple and easy modification as the artist works out the details of perspective, scale, and placement.

Next the artist may start to refine the contours, make the overall silhouette actually start to look like a human being. Sharpen the chin a bit, turn the oval eyes into recognizable outlines, put the appropriate curvature into the nose and ears.

Then as they keep working they'll start adding in general senses of color and shading, put in specific features, and in then end off with things like freckles and highlights in hair. Honestly if you've never watched a timelapse of someone drawing (who knows what they're doing) go find one - it's awesome.

There's a lot of good in this approach and to see it, consider what would happen if instead we drew portraits like a printer does - from top to bottom of the page in all of its detail all at once. If we realized we didn't like the orientation of the face or that the perspective was off, we'd have to erase *so much* detail just to make that correction. And we would have only realized this after many laborious hours putting detail into hair and foreheads! We'd

be learning slowly, and correcting expensively - a perfect recipe for expensive failure.

Instead by starting with the foundations and working up to detail the artist can confidently and easily modify precisely whatever level they are working on at the moment without having to worry about getting rid of loads of extra stuff they never had reason to add in the first place. Rather than erasing a full face, they just remove and replace a simple contour to change the position of the face. Working one level of abstraction or detail at a time makes for quick learning and cheap correction.

But note, it's not good enough to just iterate on something, you *have* to iterate on the whole. If I were to draw an ear one level of detail at a time and only then move onto the other ear, and then the nose, and so on, I end up back at the printer problem where I've put in loads of work before I realize the face is just not the right size or the proportions are off. We want to be learning not just about the components but how the components interact with one another to form the whole. So, you have to iterate on the whole at each level of abstraction or detail.

We can now see that we have an answer to our prioritization/organization problem - you should only worry

about whatever's required to deal with your current level of detail or abstraction. If there's something that's come on your radar that's going to be a level or more of detail up from where you are, log it away and don't worry about it for now - acting on it would be like filling in detail on someone's hair before you've got the face positioned. In other words we now have a clear, self directing strategy for how to choose the specific kinds of things we're going to focus on at any one time - and it's guided by whatever step we are in drawing our symbolic portrait.

In sum then, the way to prioritize work in such a way as to minimize the cost of failure is to be like an artist and iterate through levels of detail one step at a time. In doing so you'll learn much more quickly and be able to make modifications simply and cheaply in the knowledge that your foundations are solid. Iteration is the pattern to execute on.

6.5   Be Frugal

As I noted before doing as much of this stuff with pen, paper, and your imagination is one of the best ways to reduce the costs of failure. It's one thing to notice a fundamental in flaw in something that's going to require you

to blow the whole thing away when it's still sitting in your head. It's quite another to have to tell a whole bunch of developers and investors that you've gone down the wrong path. Imagination is free, development is not - use your head as long as you can.

However, at some point you're going to need feedback from the real world. This is true for two reasons. First, you'll end up reaching the boundaries of what you know and what you have data for and you'll have to start building things and running experiments in order to fill those gaps in your knowledge in. The other reason is far more nefarious - unknown unknowns. So far we've be largely talking about known unknowns, things that either you or your advisory panel know to watch out for, gaps you know are there and need to fill in. But, no matter the project you will always come across unknown unknowns once you actually start building things. In other words, no design you ever make will actually be perfectly complete, and you'll do learning along the way as you build things out.

So does this mean that all of the design we've been doing in our head is for naught? Not at all! It's still important to minimize the learning you're doing to unknown unknowns, it's far worse to fail because of something you *knew* you needed to cover and just didn't. All this means

is that the principles we've been talking about thus far in terms of building good models, being iterative in how we go about things, thinking in systems, and so on still applies even as we get into the execution and experimentation stage. However one major thing has changed - rather than the cost being some paper, graphite, and probably a little pride, resources and money are now on the line. As a result it's in our best interest to figure out how to learn and build with as little cost as possible and there are, broadly speaking [24] [33] three ways to reduce costs.

The first and most obvious is just to be aggressively frugal. For example if you're trying to understand whether people will really engage with a specific UI design you could go ahead and build the UI into an app and then test it on people. But this would really expensive. Alternatively you could use something like Figma (a mock-up building tool) to build a mock up and use that to run your tests. Or, perhaps even better, you could just sit down with users and, with markers and whiteboard in hand, design a UI they like with them in the room. Just being conscientious about being aggressively frugal goes a long way to making things (including mistakes) cheaper.

The second is sort of the reverse of this, instead of minimizing the cost of what you're going to do you break up

and minimize the goal. For example, if you're building an application that you envision having ten features you could ask yourself whether five would provide value, or two, or one, or even a half. That half may not be super viable as a product, but it might allow you to learn something essential quickly (remember learning is as much a value add). Now the point here is not that you're throwing out the rest of the features - you can certainly get to them after the first few are successful - it's just that you're breaking your problem into more bite sized, cheaper to implement pieces so that you reduce the impact of getting something wrong.

Finally, the third principle is building with a mind toward reuse. If you can build APIs or databases or whatever else in a manner that allows you to build other things more easily (and using the work you've already done) this dramatically reduces the costs of things as well. Build with a mind to reuse and you'll build less overall thereby reducing the overall costs.

In summary, at some point you're going to have to move to the execution stage in order to start building things, but, perhaps more importantly, in order to receive feedback from the real world. When this happens pretty everything stays the same - the same principles apply as before. Create with people, iterate, be scientific, remember

to work towards causes not relief of symptoms. However, what does change is the cost of getting answers because now you'll be dealing with real resources rather than just time, pen, paper, and imagination. So to that end, you can use the principles of frugality, focus, and a mind to reuse to ensure that you get feedback quickly and as cheaply as possible and in so doing reduce the risks that you cut your journey short and don't get to see the value add you want to bring come to life.

6.6 Capture it All

At this point, we've gone through *a lot* of different ideas. But what does all of this look like in reality? How do we keep track of it all? And while we keep talking about the "devil in the details" we've really just been talking in broad strokes. To my mind this all comes together in the form of a kind of "collection". The collection is a document in which all of this questioning, crafting, and collaboration can find a place.

The collection begins where it should - by capturing each of the groups of people involved. There's a section for the beneficiaries, who they are, the value we intend to bring them, and how one goes about working directly with

them. Likewise there are sections for the benefactors, developers, and advisers as well, each with their own details and processes relevant to their perspective and impact on the whole. The rest of the collection should be a collective effort among all these people and therefore capturing who the relevant people are must come first.

Second comes diagrams and documentation detailing the system we intend to change and the specifics on how we intend to change it. This is *the thing* that will be created and everything else, the iterations, mental models, experiments, cost assessments will be a means to this end. But it's important to remember that this system is beholden to those we are working with and as we learn and create will constantly change - the collection is a living document. As a living document there will always be gaps, questions, and other things to be refined. In order to not overwhelm ourselves with these it's important to start creating a queue of refinements to made to the system design, ranked by priority (driven by our iteration cycles), indicating who needs to be involved in working it out, and eventually overwritten by the conversations, conclusions, and caveats that drive the eventual conclusions. This is not just a guide to the system but to its development and evolution as well.

Next in line is where we pull in the science. This, in my mind, divides into three components. The first is a summary of what we think we know and the theory and mechanisms inherent in it today. Bringing together data into a coherent picture is not only how we go about understanding something for ourselves but is also how we end up teaching others. But alongside any theories or ideas are questions. Some of those questions need answers and this queue of unanswered questions forms the second part of our "science" section. These should each have what we want to learn, why we care, how we intend to figure it out, and, most importantly, the priority of getting an answer - remember detail only matters when your level of iteration is up for it. Finally there are the answered questions and all of the attendant data. You did work to answer these questions, what a waste it would be to lose track of what you did and what you found.

As our system comes into view we're going to start finding the work that pushes out of the world of imagination, conversation, pen, and paper and into the world of resources and costs. At this point two things become paramount - breaking things up into iterations and minimizing the costs in each of those iterations. At this point we're going to create development iterations and development time lines. Just as our system design was a cumula-

tive effort among all of our collaborators, so too will this.
Experiments can only be run with users, you need devel-
opers to build things, and benefactors to fund things. So
working together on these minimized time lines is essential.

At this point we've captured creating with others, be-
ing scientific, thinking in systems, iterating, and being fru-
gal, so are we done? Not at all. What we've dealt with so
far are the guideposts and ideas that more or less apply
across the board regardless of what you're doing. But as
you go along and work with people, think about things,
build stuff out, and make mistakes you're going to come
across innumerable considerations, questions, processes,
and the like that are helpful to your *specific* situation.
One way to think of it is like this - for every mistake you
or someone else has made in your field there is a question or
a process that, in hindsight, could've saved you from that
mistake. Capturing those questions and processes into an
algorithm for designing and developing ideas is how you
learn from past mistakes and ensure you do better next
time. So this last section is exactly that - it is your spe-
cific algo. For each issue you come across, for each mistake
you or someone else makes, capture what could've saved
you and add it to a process that ensures you engage that
new bit of wisdom at the right time. With this in hand
each idea you pursue will make pursuing both itself and

other ideas even easier. But the only way to capture it is to write it down.

So now we can see the "collection". It starts with who you're working with, why, and how. It gets into what you all are building together from a systems thinking perspective along with the queue of questions and work required to bring about greater and greater accuracy and precision in that vision. It captures the mental models and knowledge underpinning those ideas along with all of the attendant questions, research, and hypothesis that need doing or resolving. As it comes time to get feedback from the real world it captures the evolving plan on how to iterate and be frugal. And finally as you learn from doing it captures an algorithm for walking through and developing this collection in a way that draws from all the past experience you've had and you've drawn from others.

But let's step back for a moment and consider something astonishing. Suppose you start this whole thing with a horrendous idea. I don't mean an evil idea, just one couched in a lot of naivety. Through this process you'll start by engaging with people, users, developers, and benefactors, who will quickly help you see what you're missing. But in doing so it will provide the seeds for new ideas, ones better couched in reality this time. Or suppose that

you feel like you have this amazing design but it turns out that there's something horribly wrong in one of your mental models. The focus on empiricism and testing your ideas will quickly lead you to uncovering your error which in turn will allow you to go back to the drawing board and think of something better with this new information in mind. Or perhaps you, your stakeholders, and all of your data suggests you're right, and yet unknown unknowns are waiting for you around the corner. By iterating and being frugal you'll quickly learn what you need to and be able to work with your collaborators to update and pivot.

In other words, with these processes and mentalities it doesn't really matter a whole lot where you start. Even if you begin with bad ideas these guideposts and interactions will drive you closer and closer to something that does matter because you'll be getting constant real feedback from all of the things that underpin and would use or interact with whatever it is you are building. Therefore so long as you are committed and follow the feedback you will find your way to something successful eventually.

This then solves part of the problem posed in the last chapter where we asked how someone with a singular focus can end up creating value. But there is still a key piece missing here - what creates the kind of motivation where

the ideas and details can keep changing, your assumptions and designs can keep failing, and yet you still stay determinedly on the path? Without knowing where you end up, how can hope to know that you'll stay motivated, involved, and, most importantly, happy? To that question we will turn next.

Chapter 7

Systems Engineers

7.1 Diversity First

I've always held that games provide excellent ways of demonstrating and learning real world principles. As an example, take the game Settlers of Catan. The game itself is simple enough, players each gather and trade resources and then use those resources to build up and expand their respective settlements. As they do so they earn victory points and the first person to reach a specific threshold of points wins the game.

In the game resource tiles are not evenly distributed

among the players and who needs what depends on what each player is trying to achieve. As a result of this it doesn't take long before different players end up with disproportionately large stockpiles of certain resources and an absolute dearth of others. This sets things up for possibly one of the most entertaining components of the game - trade. An arena of backstabbing, failed loans, and bribes all trade in the game is based around one thing - differentials in value between different players. For example suppose I happen to have a large surplus of sheep but am in desperate need of stone to build cities. I will end up looking for players who are in the opposite position - having more stone than they really want or need but are in need of sheep. This differential in value sets us up for what is known in game theory as a positive sum game - by cooperating we will both end up with more value than either of us started out with. And if the deal is good enough others might actually look to interrupt our bargain in order to limit our perceived advantage.

This simple example demonstrates a very broad and far reaching principle that has driven quite a lot of human development - differentials in what people value creates the opportunity for positive sum games and positive sum games generate growth. Loads of other examples of this principle abound throughout history. The rush to colo-

nize the New World came from sudden access to things Europeans valued a great deal like fancy furs and silver for coinage that the New World had relatively easy access to (unfortunately no one ever thought to cooperate with the Native Americans but that is a diatribe for another essay). In the wake of global trade and global industrialization each city in the world has been able to become hyper-specialized in producing specific kinds of things allowing for loads of positive sum games that have driven a lot of the progress we've seen in the past half a century [47]. Then looking at specialized industries like health care we see this kind of pattern creating a diversification of jobs. Increasingly specialized doctors need increasingly specialized nurses, administrative staff, tools, and facilities.

In general the loop is clear. As people specialize they generate both specialized kinds of value but also specialized kinds of needs. If these needs and values get matched with other different but compatible specialists through positive sum games, the sum total value ends up larger than its parts. These additional resources (whether they be in the form of knowledge, capability, time, money, etc) can then be used to drive additional specialization to drive even more powerful positive sum games, and so on.

In sum, specialists open the opportunity for positive

sum games and positive sum games open the opportunity
for specialists - a powerful feedback loop that doesn't just
redistribute the pie through even trades (zero sum games)
but actually results in growth.

   This, however, points out something really interesting
about the nature of work and growth. In my own experi-
ence I have oftentimes (if not almost always) seen the focus
surrounding achievements go not to the *teams* but to the
stars. Sports focuses on the star players, music focuses on
the star performers, engineering focuses on the folks "at
the cutting edge". Obviously high performers are impor-
tant but positive sum games work because of *differentials
in capabilities and value*. What matters is pulling together
groups or teams that collaborate in the most powerful of
ways across a variety of different skill sets. A team of
highly compatible, highly differential players is always go-
ing to beat a team of high performers that either don't
get along or are too close to one another in capabilities.
A team of quarterbacks or strikers wouldn't get very far
against a relatively mediocre but well diversified team.

   High performance only matters in the presence of the
diversification required to take advantage of it.

7.2 Process not Product

Alright so we know positive sum games help us generate growth but we've got one problem - single positive sum games don't get us anywhere and are usually pretty hard to setup. Calling back to our game of Settlers of Catan a single trade is not going to win the game for me - I need to make repeated good trades in order to actually grow my settlements. And each trade I make has to be thought through, bargained for, and sealed. That's a lot of overhead.

In general this applies to the real world as well. Single sales don't make companies, continued, predictable sales do. So should we renegotiate every single deal, every single time? Rarely. In general it makes sense to save on the overhead as much as possible and instead of thinking about single actions, think about creating resilient processes that will continue to produce positive sum interactions for us. As Meadows points out repeatedly in her book *Thinking in Systems* [26] single interactions don't lead to long term reliable patterns of behavior, only systems do so. So rather than spending loads of time hand crafting each and every interaction it makes a lot more sense to put that time and energy into building a *process* that will reliably produce the results we want. Put another way - process over prod-

uct.

7.3   Avoiding the Chaos

Now what we've talked about so far are pretty limited, small scale interactions - positive sum processes between very specific parties. However usually meeting larger goals takes the coordination of several different positive sum processes. As an example let's take an example out of Meadow's systems zoo - a car dealer [26]. In this situation the car dealer has not one but two positive sum games to play - one with the customers and one with the car manufacturers. However, while this situation seems only trivially more complicated, it quickly illustrates what can go wrong with more complex systems. What's important in this example is that the car dealer is having to balance out how quickly she buys cars from the manufacturer with how quickly she sells them.

Now in this example, as with the real world, there are delays involved. It takes time to place the orders to the car manufacturer and it takes time to get a good sense of how customer behavior has changed. As Meadows demonstrates, these kinds of delays result in oscillations in the stock of cars at the dealership at anytime. Basically, what

happens is that if sales increases slightly, given it takes time to notice the shift a drop in inventory will result. This drop in inventory ends up pushing the car dealer to put in a large order to the manufacturer. However because this order needs to compensate not only for the loss in inventory but also the increased rate of sales at some point the inventory overshoots the sales alone. But it takes time to correct this with the manufacturer and by that point the dealer will be trying to correct downward to deal with the excess of stock. This then brings us back to a lack of stock and the cycle continues.

This however is where things get interesting. The obvious thing to do here is to remove the delays as they seem to be the source of the problem. However there is really only one delay the car dealer has any control over - her own response time to customer sales. But as Meadows demonstrates by actually simulating what happens with a shorted delay, the oscillations only get worse! More or less the quicker response also results in more dramatic and therefore over-compensatory responses. As it turns out the way to dampen the oscillations is not to reduce the perception delay but to increase it so that it better matches the delay from the car manufacturer.

This demonstrates a simple but profound principle il-

lustrated throughout Meadows' book - rational actors in complex systems do not produce rational results if they only think about their individual interactions with the system. What's required to get the system to work properly is to look at the system as a whole and tune the various interactions to work well *with one another.* And sometimes the required changes seem to make little sense within the specific components that need to make the change. Our dealer was having issues due to delays but it turned out that the solution was actually making one of the delays longer!

Our car dealership was a toy example but real examples of these principles abound. Politicians in democratic governments are reelected every few years. This makes good sense if you're trying to provide a quick feedback for your voters. However it also leads to politics that has a hard time dealing with long term issues as politicians are motivated by their immediate next upcoming election. Given the risk involved in lending money it only makes sense to receive some kind of return on investment. Yet this results in a self reinforcing feedback loop that inexorably drives money into fewer and fewer hands. The principle is clear - people can act totally rationally with respect to the issue at hand and yet drive a system to horrendous results.

What this means is quite simple - systems require system engineers. It is not enough to simply throw together a system and hope that everyone doing their part will get you the intended results. You need folks who will monitor the system as a whole and modify and improve it as needed to meet the *actual* aim of the system. Furthermore it is up to these systems engineers to notice when components of the system have grown old and need to be retired or when new components are required to meet or grow the system.

The people currently in those kinds of positions go by the title - manager. However, (at least in my experience) this is a relatively radical way of looking at a manager's role. Most of the time when thinking about management it seems that people tend to think of a manager like a general during a battle - handing out orders, monitoring progress toward goals, potential risks, etc. In the moment, this kind of work is obviously important, however to our earlier point about single trades not creating a business, single battles don't win a war. And this is where systems thinking comes in. Battles are fought by armies, but wars are fought by militaries. Militaries are composed of all the processes for recruitment, training, promoting, gathering intelligence, selecting engagements, developing new technologies, etc. Battles are just individual expressions of these systems. So if a military wants to stand a chance

of winning battles consistently they'd better not just focus on the tactics of individual battles but also work on developing the systems that drive their military. In a similar way, while managers are certainly responsible for the tactics around driving specific deliverables, they should really see those tactics as expressions of the system for which they are ultimately responsible.

Managers should be systems engineers first and tacticians second. Indeed one might even go so far as to say that any time they have to intervene they've found a flaw in their system that needs to be addressed.

7.4   Recursion through Hierarchy

The example of a military is a good one because it also illustrates a pretty general problem in systems engineering - how to deal with scale. One cannot expect a single person to manage every single subsystem inside of something so large as a country's military - there's simply not enough time to do so. In general we'd expect this kind of problem to arise in pretty much every successful system. Why? Because remember the whole point of positive sum games is to generate growth. That means positive sum systems grow too and so, if they're successful, at some point scale

is going to become an issue.

Thankfully we can take a queue from our own biology. To understand your anatomy you don't necessarily need to dive all the way down to biochemistry - understanding the general anatomical systems will do. If you want to understand those better you need only learn about the organs that compose them. Organs in turn are composed of tissues, which are composed of cells, which are composed of organelles, which are, finally, composed of biochemistry. Your body is an exquisite example of hierarchy. At each new level of complexity all of the components have clearly defined interfaces and roles which allows them to be considered, more or less, as black boxes - you don't have to understand their internal systems to understand how they work relative to the system they're a part of.

Hierarchies are how systems end up dealing with scale. In general once a system becomes overwhelmingly complicated it must find ways to divide its components into individual, independent subsystems into which all of the underlying complexity can be packed and then hidden. The resulting system will then be back to a manageable level of complexity allowing for further growth of the system.

As such, hierarchies require three things - (1) clear,

distinct roles for each component, (2) clear interfaces be-
tween those components, and (3) systems engineers who
can manage and be responsible for the internals of each
subsystem. Without these conditions the hierarchy either
doesn't effectively resolve the complexity or results in the
eventual degradation of the internal subsystems. But with
these, hierarchies can be applied recursively to allow sys-
tems to scale, at least in theory, indefinitely.

7.5   Pulling it All Together

Okay so we've noted how positive sum games enable you
to use specialists to drive growth, how thinking in terms of
systems allows you to turn that growth from an effect and
into a pattern, how systems engineers are required to get
systems to actually reach their goals, and how the scale
that eventually comes from the growth of those systems
can be handled by building hierarchies. This provides us a
useful map for thinking about how to get the most out of
our specialists, drive them towards meeting useful goals,
and, in the long run grow the capabilities and value avail-
able to us. But of all of this points out something very
simple and very profound - *organizational development is
positive sum systems engineering.*

Why does this matter? If you listen to how our world talks about the "big" issues you'll see the same thing over and over again - here's the solution that will save us. If we just build carbon sequestration technologies we'll solve climate change. If we can just elect the right leaders we'll remove poverty. Let's all get together and clean up the local lake so we don't have to deal with pollution anymore. Now don't get me wrong, all of these things would be great! However none of these solutions address the fact of the matter that the systems that got us into these messes into the first place will still be there. It may seem like the lack of a solution means nothing's there but *systems always exist and the current behavior (or lack thereof) is a result of them.*

Furthermore as we saw a few sections ago, adding helpful technology can just create even more devastation. For example, our creating better and better fishing vessels has actually resulted in fewer and fewer fish [26] because we haven't addressed the underlying lack of sustainability in the underlying system!

As a result, rather than trying to pull together specialists to create the next grand new technology or power the next great intervention, we should instead be trying to engineer the kinds of systems that wouldn't drive us toward

these problems in the first place. Indeed if we build the right systems, we will end up empowering the underlying specialists to self evolve the needed solutions. However if we focus only on the solution and leave the old system in place that same system will eventually just erode our efforts away. Organization development is not about creating solutions, its about engineering effective systems.

7.6   What is a System Engineer?

Okay at this point it should be pretty clear that organizational development is all about creating powerful systems - it's the job of a systems engineer of sorts. Yet we haven't really been very specific about what a systems engineer is. And it's very important we're careful about this because if we're not we'll end up sending folks down paths that will simply overwhelm them (as it has done me several times during my career thus far).

To see how this is the case consider for a moment that you have just become the mayor of a town. What is your responsibility? Is it really the well-being of all the folks living in the town along with all of the infrastructure, land, water, and resources? Certainly not, right? I mean that would simply be too much for anyone to really bear. For

example suppose there arises an issue with a local water supply. Maybe some kind of pollution is happening. To address the issue (in a systematic way) would mean getting down there, thoroughly understanding what has led to the issue, what other system components relates to those causes, and then a lot of design, implementation, feedback, and trial and error to create and execute upon a robust solution. All of that is a full time job in and of itself and, within a town, there'll be loads of these kinds of problems *all the time*!

Now at this point you might think to yourself, isn't this where hierarchies come in? To some extent yes - the mayor could simply delegate to the right people to get things fixed. But that still requires that the right people are even present, that the issue has been raised and instrumented, that the resources needed to fix the issue can be granted, and so on. So let's look at this from a slightly different perspective.

We know that there needs to be someone who's *full* attention is dedicated to just this pollution problem. I.e. there is an artifact of our system that has been identified as less than desirable and we need someone who will go in, understand the system from the point of view of this artifact, *design* a new set of roles and positive sum pro-

cesses to go into the system (as well as the ways in which those roles and processes will interact with the broader system), drive implementation of those processes, and see the whole thing to its (hopefully) merry conclusion. Let's suppose that this is the role of a *systems engineer*. I.e. instead of systems engineers being responsible for the whole system we are now saying that they simply latch onto a specific undesired artifact (or desired but not present artifact) of the system and work to solve *that* specific issue by adding in new roles, processes, and interfaces. Does this mode of thinking work?

Well you may point out, and rightfully so, that our mayor had to go and try to do this by themselves because there were no systems designers there in the first place. So what good is a systems engineer if they aren't being directed to the right problems? Well instead of looking at this as a need for specific centralized direction, we could instead look at this lack of systems engineers focusing on these kinds of problems as a bad artifact of the system - i.e. we just a need a system engineer to solve this artifact and then the "mayor" need no longer worry about these kinds of problems because the system will "self heal", so to speak.

And if systems engineers can patch up issues in a lack of

systems engineers then we find ourselves in a system that can *self organize*! To be specific the "algorithm" would be as follows:

1. Become aware of an artifact that needs resolving (or a value proposition that needs adding)

2. Ask yourself if your awareness is thanks to the system or clearly in contrast to it

3. If it's the former simply address the artifact you started with

4. If it's the latter you've found an artifact of systems engineer not being driven towards problems of these kind - repeat from step 1.

Now note that while this system is self organizing, there's no reason why it won't lead to things like "mayors". However the roles of these central figures of authority will be to operate within the bounds of responsibility set out by these systems engineers rather than being responsible for the system in its *utter entirety*.

Furthermore note that before this the central authority had to understand the *whole* system *in full* - a task that quickly becomes impossible for any one human being

as we rise to higher and higher levels of complexity. But now, systems engineers only need to understand the parts of systems *pertinent to the value they are trying to bring.* A much more contained and manageable problem!

So at this point we know what our systems engineers are - they seek out new value that needs adding to a system, design robust modifications to the system, drive execution of those modifications, and then seek out the next value add. And assuming they continue to ask the meta question in step 2 above, they will self organize and needn't worry about the system as a whole. Certainly now a manageable role that has specific kinds of skills that go along with it - far better than our imaginary and completely overwhelmed mayor. But we can now see why it was so important to nail this down because it should be clear that organization developers do not *run* organizations, they move about and update individual components of the system and in so doing build, overtime, a *self running* system. Only by approaching it this way do we have any hope of being able to scale a system beyond the bounds of any one person's ability to think and operate. Something that's totally necessary in our increasingly complex and wonderful world.

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