
*** Thesis #4: Machine Maps ***

Warren Buffett - when he was exactly [our age](#) - bought shares in [Sanborn Map](#). The business was simple: fire insurers, as they expanded nationally, needed a way to set insurance pricing on a granular, block-by-block basis (based on proximity to construction, fire stations, water mains, etc) without employing boots on the ground in every city and town in America. Sanborn employed surveyors around the US to report updates to its NYC headquarters, where its cartographers created thousands of highly-detailed maps. The maps were subsequently printed into [50-pound books](#) and delivered to insurance companies where underwriters would use them to [track exposures](#) and set rates. Every year, insurers bought paste-on “correction slips” to overlay over the pages with recent updates. On a unit basis Sanborn spent \$175/yr to produce, maintain, deliver, and sell the map for the typical city or town, and insurers - of which there were typically at least 2 in any given town - paid \$125/yr for access. Sanborn sold its maps to both insurers and enjoyed 30% operating margins. The bulk of its revenues came from 30 or so fire insurers paying \$75K/yr (\$1.5M/yr post-inflation), though it also sold maps to utilities, mortgage companies, and tax agencies. A handful of competitors offered cheaper maps, but none rivaled Sanborn’s coverage of 10K+ locations, plus insurers were wary of changing the workflows their underwriters had been trained on for decades.⁴

It’s been 65 years, but the mapping business has barely changed. Instead of a 50-pound book, a city map today “weighs” anywhere between 5 (satellite), 50 (point-clouds), or 500 (LIDAR) gigabytes, depending on the resolution; instead of once per year, maps refresh in minutes, hours, or days; and instead of human surveyors driving around cities and sending paper reports by mail, today’s *mapmakers* collect and collate data from cameras and other sensors mounted on [drones](#), [telescopes](#), [billboards](#), [smartphones](#), [autonomous vehicles](#), and even [augmented reality headsets](#). The core economics of *mapping* remain the same: you pay only *once* to collect, create, and maintain each map, and then resell those maps to *several* different customers. In other words, costs scale ~linearly with coverage (i.e., number of maps) while revenues scale ~linearly with demand (i.e., number of customers or queries). The key unlock is reselling each map to multiple different customers, creating powerful operating leverage.

There is one important way the mapping business *has* changed since Buffett’s time: the **customers**. Fire insurers and railroads are no longer the biggest buyers of maps, not by a long shot. Today’s *mapmakers* can resell maps to oligopolists in [food](#) and [parcel](#) delivery, [telecommunications](#) and [airlines](#), [ridesharing](#) and [e-mobility](#), [electric vehicles](#) and [charging stations](#), [high-frequency](#) and [commodities](#) trading, and other industries that didn’t exist in Sanborn’s time but now eclipse the fire insurance industry in size. The biggest *mapmakers* serve [thousands of customers](#) and are [heavily diversified](#) across verticals and geos. Customers pay a similar amount for maps, but the most useful maps can be re-sold to not just two, but as many as 5-10 different customers.⁵ The subsequent operating leverage, we believe, means the leading mapping businesses will generate 40-50% EBITDA margins in the future, vs 20-30% today.

But that’s not why we are excited to invest in mapping businesses... the thesis is called **machine maps** for a reason. We believe AI - call it agents, or robots, or autonomous systems - will grow to become by far the biggest users of maps. Increasingly-sophisticated use cases for AI will require a richer and faster understanding of the physical world around its embodiment. Whether it lives on their phone, glasses, or cars, users expect agents to understand the world the same way they do. Today, my Meta glasses can’t tell me if there’s a line at the coffee shop down the street; my Tesla can’t tell if the noise I heard was a car accident on the next block; and my ChatGPT can’t tell what I had for lunch or what I’m watching on TV.

⁴ The numbers here are illustrative estimates based on figures in Buffett’s letter and the Library of Congress archives.

⁵ Sanborn’s 30 insurance customers paid ~\$1.5M/yr, adjusted for inflation, for data collected by a few hundred human surveyors. A century later, Planet Lab’s 1,000 customers pay an [average of ~\\$300K/yr](#) for data collected by its few hundred LEO satellites.

While it represents a massive new source of demand, AI challenges the current business model of *map-makers* in similar ways to software. The shift to [token-based consumption](#) models means agents will demand increasingly-granular datasets (maps) to serve their specific needs. Mathematically, selling a larger amount of smaller (more granular) maps makes it tougher to re-sell the *average* map several times, which as previously discussed is the key driver of mapmakers' operating leverage. The issue arises when there's a **granularity mismatch** (think: duration mismatch) between the level at which the mapmaker can control the costs of producing an incremental map, and the level at which it re-sells those maps to its customers. Sanborn, for example, could hire a surveyor to monitor a metro area and be relatively certain it would be able to amortize those costs across at least two insurance customers. For a company like Planet Labs, which launched and operates a constellation of 200+ LEO satellites that effectively provides global coverage, the incremental time and cost to point a satellite to a new angle to serve new customers is relatively low—on the order of days, or thousands of dollars. Accordingly, the cheapest “subscription” to [Planet Labs' API](#) costs \$2.7K and provides access to maps of 1 hectare (roughly two football fields) or larger—levels at which the company can *granularity-match* its incremental mapping costs vs demand.

Legacy mapmakers, like software incumbents, are at crossroads: enterprise customers bring sticky, high-margin revenues, but little growth. Meanwhile, usage of their APIs is booming thanks to agents, but it's unclear if the usage is contributing positive or negative gross profits, or potentially cannibalizing the legacy business. TomTom raised the price of [API credits by +50%](#) this month (basic tiles are cheaper, but all the value-add features are more expensive, some by 5-10x); Mapbox is more API-native and raised prices for its map API by [+10x back in 2019](#) and its search API (the thing that autocompletes an address when you type into a search bar) by [+2-4x in 2024](#). Mapmakers are converging on the same business model: an up-front SaaS fee (or minimum commitment) to get in the door, consumption-based fees on map access, and consumption-based fees on compute. Mapping features will increasingly get unbundled, with mapmakers publishing ever-more-complex [rate cards](#) to drive price discrimination (the agents, in any case, won't mind). Other layers of the value chain will compete away any profits from reselling compute and software over the long-term, and only the margins on consumption-based map access will remain.

At recent IC meetings, we've often found ourselves discussing what a \$100B mapmaker could look like. Such a business would need to be *granularity-matched*, i.e. the size of the “hex” or individual map it produces and sells should be small enough that the incremental cost of expanding coverage is not too high, but large enough that each individual hex (on average) can be re-sold multiple times. It would own a map that gives agents or robots *superpower-like capabilities* relative to what users expect today. Most importantly, it would need to be run by an entrepreneur with both the focus and meticulousness to build a world-class map, and the relationships and hustle to drive the utilization and monetization of that map.

Our debates led to several investments over the years into companies we believe fit all three criteria, including our first two Fund II investments, [Skymapper](#) and [Rumi](#). Skymapper is a *machine map* that connects telescopes of all shapes and sizes into a unified global network that gives agents the superpower of being able to *see the night sky*. Rumi is a *machine map* that gives agents the superpower to *understand media* alongside users as they watch TV or stream. In both cases, it became obvious during diligence that the founders had a head-start on *granularity-matching* their mapmaker. Franck Marchis, CEO of Skymapper, previously co-founded a [consumer telescope manufacturer](#) with 10K+ global installs and can expand his *sky map* at very low costs by simply sending [\\$350 routers](#) to a few of those existing telescope-owners. Niko Cunningham, CEO of Rumi, previously led the AI efforts at [Udacity](#) and [Koemei](#), and by the time we met him had recruited a team of AI engineers - paid out of his own pocket - to train edge models powerful enough to recognize and understand what users were watching in real-time, but lightweight enough to run on consumers' smartphones and thereby avoid any hosted inference costs.



Those of you who know the story of Sanborn should be skeptical of our bullishness. In the 1920s, insurers began using filing cabinets as primitive databases: policy details - address, policyholder, inspections, etc - were written on an index card; one card per policy; and filed concentrically alongside others in the same neighborhood, town, county. This fundamentally changed underwriters' workflows: instead of tracking regional exposure by [writing in the margins](#) of Sanborn's books, they could simply count the number of cards in a file. If they wanted to compare the premiums charged to homes on an adjacent block, that was easy too. Sanborn books were still needed for some things, like pricing policies in a new neighborhood, but underwriters' reliance on them steadily declined. By the 1950s insurers were adopting *carding* not just for underwriting but also functions like policy management and claims. They began rejecting Sanborn's modest annual price increases, something they'd never done before, instead threatening to switch to competitors if they were not given a discount. Sanborn's profits were down -80% and its shares down -60% by the time Buffett invested, and in fact he was never a fan of the mapping business, saying he paid *"70 cents on the dollar for [Sanborn's] investment portfolio with the map business thrown in for nothing."*

Mapmakers, moreso than most other businesses, are perpetually at risk of technological disruption. The business requires making long-term investments to source and maintain proprietary datasets. Map customers, however, do not buy datasets—they buy inputs that unlock a specific outcome. If a new input achieves that outcome faster or at a lower cost, customers will make the switch, often before mapmakers can recoup their investment. Even worse, mapping disruptors tend to come from non-obvious places. Remember the paper maps you would bring on road trips in the '90s? Those makers of those maps were disrupted by a company that started out [as a defense contractor](#), which was disrupted by a company that started out [as a search engine](#), which is being disrupted by a company that started out [as a non-profit](#), all in the span of thirty years. Suffice to say, it's no surprise Buffett was not a fan of *mapmaker* businesses.

Some technologies, though, are clearly more extensible, and make for more durable businesses, than others. Passive optical sensors - **cameras** - are the single most powerful tool in the mapmaking toolkit. The sun is the strongest source of energy in the solar system, so harnessing its energy to produce data has structural cost advantages over almost any other method. The things we do with cameras today would have been called science fiction twenty years ago: on a computer with wheels, cameras are [better drivers than humans](#); hooked up to an alarm, they'll keep you [safer than a body guard](#); on a smartphone, they'll detect [anemia](#), [jaundice](#), and [skin cancer](#) before your doctor; on drones, they make great building inspectors, photographers, and [snipers](#); and on a satellite, they could [improve your trading performance](#), at least for a few years. For every one of these, we heard the same arguments - *"cameras will never beat [X] technology at [Y] use case because of [Z] limitation"* - we hear today when we tell people that within a decade, a camera attached to a computer, a motor, and metal claws will [perform surgeries better than a surgeon](#), or that cameras [smaller than a grain of sand](#) will line the fabric of their clothing and furniture. Cameras, like solar panels, are an economic innovation as much as a technical one: the semiconductors inside camera lenses are actually [relatively simple](#) (vs CPUs or GPUs), many competent companies know how to produce them well, the hardware is commoditized around a handful of standard performance metrics with no software lock-in, and manufacturers produce several billion new units of them each year.

Our reverence for the camera lens has kept us from investing in *machine maps* levered to any other technology ([radiowaves](#), [lasers](#), [radar](#)) as their primary source of proprietary data, as well as those using multi-sensor devices for a dedicated end-market ([weather](#), [air quality](#), [flight tracking](#)). Instead, we focused on *mapmakers* whose data can serve a wide variety of industries, and who source data from the tens of billions of camera lenses already in circulation: for example on smartcars, like [Natix](#), and smartphones, like [Ovr](#), two Fund I portfolio companies. As cameras get cheaper, smaller, and higher-resolution, the marginal cost of expanding the map declines, *granularity-matching* becomes easier, and *mapmakers* can "pass on the savings" to their customers by increasing the fidelity and granularity of their map APIs.

Like any other map, **machine maps** are most valuable in high-traffic, high-density areas. Physical AI will emerge first in the places humans already spend time: malls, airports, warehouses, kitchens, bedrooms. Fund I has made two investments, [Auki](#) and [Meshmap](#), in *machine maps* for high-density spaces: grocery stores and city streets, respectively. Coincidentally, both companies started off as AR game developers.⁶

When we first spoke to Auki's founder Nils Pihl in late 2023, we knew we had to meet him in person. I flew shortly thereafter to Hong Kong, where - after a long hike up [Tai Mo Shan](#), the city's tallest mountain, where at the peak we saw armed Chinese military guarding a [massive satellite](#) - Nils told us about his business. His first product was a game where two users in the same room, wearing AR headsets, could play *Magic: The Gathering* (a tabletop card game that birthed the [first Bitcoin exchange](#)) with interactive AR graphics overlaid on top of the physical board. The main challenge was getting the graphics to appear in the "same" physical location for both users: the two headsets had no awareness of each other's relative location, and there were no software tools available that could fix it. This issue is much deeper than AR headsets, as it applies to any two machines that need to operate or collaborate in shared physical space.

Today, Auki primarily serves grocery store chains who pay six to seven figures annually to license its mapping technology. A single grocery store might house a few hundred people at peak times, and - between smartphones, [security cameras](#), [cleaning robots](#), [inventory robots](#) - a few thousand machines. Given [razor-thin margins](#) in the grocery business, retailers prioritize technology investments that cut costs (e.g., by reducing human labor or inventory needs) or, ideally, drive new revenue streams (e.g., launching [advertising networks](#)). Grocery chains make particularly good customers for robotics companies, because their existing warehouses and logistics infrastructure can be used as mini "service centers" for the robots, which require frequent repair and updates after in-the-field work. Because information about what goes on inside their stores is highly commercially-sensitive, grocery stores license Auki's technology but retain ownership over their *machine maps*. Auki re-invests its revenues into testing cutting-edge technologies at its [robotic grocery lab](#), where grocery execs inspect the [real-world performance](#) of humanoid, wheeled, wearable, flying, and other types of robots in a real-world setting, all powered by Auki's *machine maps*.

Ryan Rzepecki, founder of Meshmap, describes himself as an *urbanist and entrepreneur*—in that order. After [turning down](#) a term sheet from Sequoia to [sell his bike-sharing company](#) to Uber in 2019, he self-financed a game development studio targeting the nascent market of AR/VR headsets, which at the time had an install base of roughly 30M (the number has since doubled). There, he ran into a similar problem: every time he wanted to create a game based in a new location, it would cost a few hundred thousand dollars to create a map accurate enough to overlay virtual AR experiences over the physical terrain. After testing dozens of different technologies, he was able to cut those costs down by more than half using "[prosumer](#)"-grade [LIDAR scanners](#) and software optimizations, but it still wasn't enough—spending tens of thousands of dollars on each map broke the gaming studio's economics. He figured the maps of the locations he most wanted to build games in - Times Square, Hollywood Boulevard, the Ferry Building - should be valuable to lots of companies, but couldn't find a provider. The only product that came close was Niantic's [spatial API](#), built on [30B+ photos](#) captured by the [50M+ users](#) of the breakout game PokemonGo (which Niantic later [sold for \\$3.5B](#) to focus on 'spatial computing', i.e. *mapmaking*); but even its maps are not [granular](#) or [cheap](#) to support a fun and engaging AR game. Ryan incorporated Meshmap in 2024 to solve this problem for all developers, and shortly thereafter we invested in his pre-seed round. Today the company is focused on bootstrapping high-value use cases for its maps directly, including via [consumer AR experiences](#) where users walk around cities like NYC and San Juan in self-guided tours.

⁶ At least every few years, a pool of extremely talented entrepreneurs gets overlooked by investors for being early to a trend that looks, at the time, like a toy. The teenage sneakerheads who were botting designer shoe drops in 2019 are running billion dollar [fintech](#) and [creator](#) platforms. The nerds tinkering with tokens in 2017 are now running billion dollar [exchanges](#) and lenders. We've found that we meet an unusually talented number of founders who were building AR/VR games in the 2022-2024 era.

The last *mapmaker* we've backed (so far!) isn't focused on creating maps of the highest-trafficked areas, but of the most-*critical* areas of society - infrastructure like cellular towers, power plants, datacenters, and airports - using flying cameras, aka **drones**. [REDACTED]

[REDACTED] Hedge funds, for example, use Raad's maps to [track progress of hyperscaler datacenter buildouts](#) ahead of earnings; Raad provides 10x+ better resolution (3cm vs 30cm) than the satellite data they currently get. Analytics companies resell Raad's map data to telcos, utilities, and REITs, who need a real-time view of their most valuable assets. Today, Raad's drones are piloted by licensed independent contractors on a job-by-job basis [REDACTED] but eventually they will fly themselves (the main blocker is regulation). Raad's revenues are exploding, up over [REDACTED] YoY, with highly-diversified growth—no single customer represents more than [REDACTED]th of revenues, and no single industry more than [REDACTED]. Churn is exceptionally low given industrial customers need to monitor their assets on an ongoing basis, and hedge funds need it at least quarterly for trading on earnings. [REDACTED]

When we met Teej Ragsdale to learn about his new company, Raad, the company was not even focused on drones. The original plan was to deploy multi-sensor weather stations and sell *weather maps* to utilities and traders seeking to hedge and arb power markets. [REDACTED]

[REDACTED] In early 2023 we invested in Raad's pre-seed round alongside our friends at [Montauk](#) and [Tribe](#), making the decision to back an exceptional founder despite our reservations on the business model of selling *weather maps*. The bet, so far, has paid off: Raad is one of our fastest-growing portfolio companies. Following our investment, it quickly became clear that advances in AI and computer vision were obviating the need for dedicated weather sensors; with [enough cameras pointed at the sky](#), you could predict the weather with comparable accuracy. Raad pivoted to putting cameras on drones, and the rest is history. The experience taught us (once again) that we are in the business of backing the jockey, not the horse.

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In short, we've made a concentrated and non-consensus bet on *mapmaking* businesses. We believe investors are underestimating both the **scale of demand** that agents and robots will have for maps, and also the **operating leverage** *mapmakers* experience when they sell the same map to several customers. Globally, we believe *mapmakers* broadly defined will grow from roughly \$10-20B of revenue at 20% operating margins today to \$100B of revenue at 35% margins over a decade. Though we acknowledge *mapmakers* carry substantial risk of disruption, we think the ones betting enduring technology shifts - like cameras - can build durable businesses and in fact benefit from the tailwinds to their unit economics. We tend to avoid *mapmakers* based on non-camera technologies, but are willing to bet on exceptional founders who disagree - temporarily or permanently - with our biases. Given they represent a meaningful percentage of the capital you've entrusted to us, we felt we owe you a detailed explanation of our views. We are actively working to sharpen our mapmaker thesis, so if you know operators, investors, and especially entrepreneurs thinking along similar lines, we greatly appreciate any introductions or insights.

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[REDACTED]