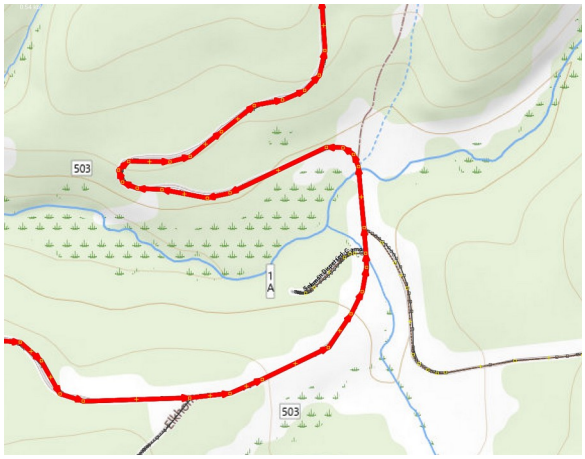
Ground-Truthing MVUM Highways

This is a long and detailed deep tech dive about field mapping in remote areas to improve OpenStreetMap highway data for emergency response. While there is little obvious discussion of OSM, it's all about improving OSM.

Recently I've been digging deep into various external datasets, namely MVUM roads in national forests, and hiking trails. As my conflation software, OSM Merge is now generating good results, I'm working on conflating these official datasets to improve what's currently in OpenStreetMap. Some of the fun is that the data is often inconsistent. Some of this appears to be related to the age of the data. My assumption is that some of this government maintained datasets date back to early digital GPS, and probably got converted between formats several times over the years. This is just a guess of course, but not unlikely. The recent release of vector map tile sets appears to be correct and accurate, but isn't in a usable format.

The issue comes down to how to handle minor differences in the map data, primarily referring to US Forest Service reference numbers. When navigating in remote areas, these minor difficulties can lead to navigation problems when your maps don't agree. The problem is about whether a reference number has a .1 prefixed or not. All the MVUM paper maps rarely display the .1 In the digital data, sometimes it's there and sometimes it's not. My guess is this was dropped to avoid clutter on the map.



For extra fun, often the sign in the national forest also lacks the .1 suffix, but sometimes it does. I wonder if the issue is the same, old signs lack the .1 suffix, newer signs include it. This may all seem meaningless, unless you happen to be way out on an MVUM highway wondering how to get back to your actual destination. And some areas are a nest of jeep and ATV tracks, so making the wrong turn can lead to disintegrating highway conditions. Often turning around can be very difficult. A few times I've had to back up long distances on very bad roads.

Those of us that spend a lot of time in these remote areas carry multiple maps, paper, digital, and mobile app. If you stop to compare them, then the real fun starts.

My goal is improving the quality of remote highway data in OSM as an aid to emergency response. For larger wildland fires, many of the fire fighters are from out of state. They depend on good maps since they aren't familiar with the area. There is a mix of mobile apps used, but most all of them have

OSM as an optional basemap. So improving OSM improves access and safety for fire fighters. In addition, any access to get resources (water & people) deep into the backcountry to fight a fire can make a big difference.

Ground Truthing

Why do ground truthing if this is just conflating datasets ? Since the original datasets have a variety of fields we might want, like the surface type, the smoothness, and various access flags. I was curious how accurate these tags were, plus checking the reference numbers of course.

The USDA has this document on Road Maintainace Guidelines, which I found very useful as it has multiple images for each category, which a rated on a 1-5 scale. These images conveniently are very similar to the images on the OSM wiki, but I wanted to drive some of them. There is a big difference between **smoothness=bad** and **smoothness=very_bad**. If an OSM highway feature is lacking these tags, it's good to know they are reasonably accurate, and steer passenger cars away from **smoothness=very_bad**.

The other big issue is how up to date is the USDA dataset ? Something I've noticed in years of being in the backcountry is some roads stopped being maintained a long time ago, and what was a bad road then, may be very bad now. My assumption is OSM is probably more up to date on the highway condition, so during conflation these aren't changed.

However many highway features in these remote areas are only tagged with **highway=track**, so in that case these should be added to OSM. Course if a road in the USDA dataset is tagged with **smoothness=very_bad**, it probably hasn't gotten any better. The other issue is access changes over time, sometimes recently. This track in OSM very recently (the backhoe was up the road) was not only closed, but dug up. That obviously will not be in any of the datasets, but in this case, OSM will be more accurate and up to date.

OSM Merge

OSM Merge is a project I wrote to help process the data, do quality verification, and enable a fast and efficient mapper work flow. Since we're talking about a lot of data, I'll burn out fixing the mess long before I'm done if it isn't efficient. Parts of this software I mention in my SOTM-US talk, OSM For Fire-Fighting, but it's continued to evolve since then. OSM Merge handles two really important tasks, making the data consistent for conflation, and doing data quality checks and fixing them where possible. All the datasets have bugs, but since we're doing a deep analysis, we can do that. While

there are a few other open source projects focused on OSM conflation, none seem very comprehensive.

As an experienced software engineer, and emergency responder who often uses these remote roads, I figured this was something I could fix. And I wanted the software to be something others could use since there is a huge amount of data. I'm just focused on my local states. There's a lot of infrastructure required just to make good data extracts for conflation if you want to do more than a small area.

There have been multiple conversions of the MVUM (and TIGER) datasets in the past, most seem to be a one-off project, and not maintained. The conversion process to a consistent schema needs to be repeatable and as dependable as possible. That allows making changes to the conversion software as obscure data quality issues come up during conflation. It takes a lot of time to dig through the original datasets so it's more efficient to be able to trust the conversion to an OSM tagging schema. Many fields in the original datasets are ignored as well, only adding to OSM what is wanted with no bloat. Existing tag bloat in OSM (some of this data was imported in full with no conversion) is also deleted.

Once the external dataset is converted, then it gets compared to current OSM. Tags between OSM and the external dataset are merged, but tagged for quick validation. There is much more detailed documentation on OSM Merge and the conversion and conflation processes in the github repository.

Software Testing

Since my conflation software keeps finding interesting differences in the datasets, I decided to do some ground-truthing while the weather was still nice. Many of the MVUM roads have seasonal closures, and various access restrictions. Last time I was in this area after SOTM-US 2024, all the gates were still closed. Much of this has been imported into OSM, along with TIGER. Being a remote area, I guess some data is better than none. But it can effect navigation, and I don't want to contribute to anyone's future navigation problems.

Testing the post conflation results seemed like a good idea, and I often find I can get into a good debugging or documentation writing head-space when camping. I fixed a major bug while on this trip on one of my work days, and the results of conflation are now good to use.

Datasets

Obviously conflation as well as navigation in a remote area uses multiple datasets. Here's a short summary of the datasets and mobile apps I'm using. Finding good quality external datasets with an appropriate license for OSM can take a long time, lots of web searching. Sometimes the government datasets exist on different servers, but are much older versions. Usually the data doesn't appear to change much over the years, course that means it could also be out of date. Often links to a dataset are on a dead server, so you have to look for a newer source. The other issue is many government agencies have been shifting to ArcGIS Online, where the data is viewable, but you can't download it anymore. While Avenza maps are useful for recreational users, sometimes that is the only available

format, and is useless for mapping. At least the national forest and park services are continuing to improve public access to map data.

There are also county or state datasets available. These don't cover the remote highways in a national forest, only the county designated ones. These datasets are addresses, parcels, building footprints, county or state maintained roads. The licenses vary though, not all are suitable for OSM. I do try to add the county reference number or name for an MVUM road if it exists, but those are separate projects.

S1 Mobile Mapper

The other day I stumbled across the S1 Mobile app, which is maintained by the BLM. What's really nice is this uses the latest vector tile package as mentioned above. It has private and public property boundaries and accurate road data. While I primarily use Osmand, it's useful to be able to check the official source when I'm in the backcountry, and all OSM as is **highway=track**. It has support for public maps, but also has support for BLM mobile mapping needs, and data collection. In covers all public lands, so national forests too. It doesn't do any navigation, but I've found it useful to know where I am when the other datasets are lacking. It also display public and private property boundaries.

OpenStreetMap

As mentioned, Osmand is my primary backcountry navigation app. Mine of course is loaded with external datasets, map underlays and overlays, tweaks to the rendering. I compare Osmand navigation with a commercial Garmin GPS and Google Maps all the time. I build Osmand from source every few weeks to test new functionality. While I am not a heavy StreetComplete user, it's another great app for updating highway metadata.

MVUM

This is the USDA Motor Vehicle Use Map (MVUM), and has all the highways in a national forest. This datasets contains much metadata on each highway, so is a great source of data to improve OSM. Among other details like the name and reference number, it also contains access information, what type of vehicle can drive the highways, the surface, and whether you need a high clearance or specialized off-road vehicle. Obviously this is all useful metadata if you are route planning in a remote area. Some of it has already been imported into OSM, although not always all the fields since it's a hassle to have to manually convert the data to an OSM tagging schema.

My OSM Merge project has a program to convert the MVUM dataset to an OSM tagging schema, and do other data cleanup before conflation. I've tested this by processing the MVUM data for multiple states. There are bugs in the MVUM dataset as mentioned, not all can be fixed until validating the conflation. This definitely falls under the category of an automated edit, so we want to be really careful and truly validate everything and have community support. It's very obvious looking at the current status of MVUM data in OSM, this has obviously been ignored in the past. Nonexistent tags have been added from the original dataset, there's typos, and bad reference numbers. More information on converting MVUM data is in this document. Information on conflating the post converted data is in this other document.

Trails

Trails and highways are similar when it comes to map data. The only real difference is a few tags. Trails don't use **tracktype**, and do use (hopefully) **sac_scale**. While there is an MVUM dataset for trails, but that's focused on specialized off-road vehicles like an ATV or dirt-bike. For trails I'm primarily referring to the National Park Service Trails dataset, and the trail extract from the Vector topographical dataset. Here is a document describing the conversion of NPS Trail data. Once converted, the conflation process is the same. The conflation software understands the difference between hiking trails and vehicle accessible highways

Topographical

I recently stumbled across the new USDA vector map tile packages. These all use reference numbers with the .1 suffix, so I assume that's official even though it disagrees with the older datasets. The downside with these files is that QGIS is the only open source program that can load them. These seem to be up to date, and don't have the bugs in the publicly available datasets. These unfortunately don't work as a basemap in JOSM, but they are very useful when attempting to decide on which version of the official datasets is correct.

I use the older Topographical vector data files for 7.5 quads as one of my official data sources. This data isn't very good, and is very incomplete when it comes to tags. Sometimes is does have a highway or trail name that the other datasets have, which is good validation conflation has identified the correct highway segment. The Vector Tile Package is much better, but isn't usable yet.

Power Management

When field mapping in remote areas, hotels are far away over bad roads, so I camp in the area I'm mapping. Since I may be out in the field for a week or more, I have a solar power system on my truck topper. These are two really ancient Unisolar unbreakable PV panels for 128W of power. Unlike traditional glass PV panels, these work much better

under partial shade. While in full sunlight they are less efficient the glass PV panels, being able to deal in shady campsites is a plus.

In addition, I use a 105AH AGM battery that charges off the solar panels. The two panels supply around 7.8AH, more or less depending on the sunlight. I prefer AGM or Lead Acid batteries over Lithium. With an AGM battery, you can only use 50% of it without damaging the battery, unlike a Lithium battery. So in my case, I have 50AH to use every day. Since most of my devices use around 12VDC @ 5A, that's 10 hours of usage possible. Course then you need to recharge the truck battery by however much you are using. So assuming you get 6 hours of good sunlight, generating 7AH per hours, that's the recharge time. I try to think of it this way, I need an hour of sunlight per device per hour of usage, or over several days the spare truck battery will slowly discharge, and eventually you need to stop and let it recover. What I often do is alternate, a work day using all devices, and then a rest day where I enjoy being in the deep forest or mountains.

An important solar power concept is called PV Direct. When the sun is shining, and your truck battery is mostly charged, you can use more power without pulling from the spare battery. I often use mid day as the best time for working, as I can use and charge multiple devices without depleting the truck battery.

Devices

When I'm out field mapping I of course have more digital hardware than one should sensibly take camping. The whole point of going camping is disconnecting from our devices. For me, the best camping is dropping offline for awhile. But field mapping at it's best is a working vacation, but the trick is to not forget to have fun. And often the best thing to do while charging your devices is to go do something else. Go hiking, cook a great meal, open a beer, read a book, make some tea, etc… do camping stuff and enjoy where you are.

Something else to consider when living off of batteries is the temperature. Cold makes batteries discharge faster, so you may find yourself sleeping with your devices in your sleeping bag… Or you can keep them plugged in all night if you feel good about your power management. In the winter this becomes more of a problem as there is less hours of strong sun to charge the truck battery, so you have to be really efficient. I have gone to bed with a fully charged laptop, only to find the battery dead in the morning. Forget suspending your laptop, just shut it down Also often in the winter the evening power consumption goes up as you are running lights, working on your laptop from your sleeping bag (no heater), etc… I always carry candles in case I screw up, or bad weather causes a power crises.

Tablets & Phones

All of the field data collection software runs on mobile devices. This is good, as they all have good battery life, and are easy to charge. If you doing the type of field mapping that requires lots of driving, you can make due by just charging your devices while driving. But that would require hours of driving every day, so not practical for most field mapping. The only time I do that is when mapping amenities in small remote towns where I have to drive 30+ minutes between each one.

Most phones and tablets will run all day or more on a charge, although heavy GPS usage makes the battery discharge faster, especially if you disable duty cycling of your GPS. These usually need 12VDC @ 4A to charge. Pay attention as the amperage a device needs to charge adds up… It usually takes about 2-3 hours to charge each device. Whether you charge slow or fast, it's the same amount of power.

Charging A Laptop

While older laptops could run off a 12VDC power system, all the new laptops from Apple, Dell, etc… all want 19VDC. There are two ways to do this. He easiest is to buy an after market DC power supply with a step-up transformer and cigarette lighter plug. This puts out 19VDC @ 4.74A. This is the best solution, as you can use the laptop while charging. Note that any heavy computation on your laptop will pull more power than just idling. When not online, set airplane mode to extend your battery life as much as possible.

Older devices used to be a able to run using a 65W car adapter, but no more. Most modern phones & tablets need at least 95W to charge. Newer car adapters that supply 100W or more are common, the downside being I have a box of older 65W ones that are now useless. At 100W, you can charge a laptop off a USB car charger. One thing to be conscious of is your USB cable, not all are created equal. Some USB cables use such a small gauge wire it suffers from DC Voltage Drop problems. So use a heavy duty USB cable to avoid problems. This will charge a laptop, and your phone too, so a good solution other than one problem. It's barely enough power to use your laptop while charging. The charging icon will go on and off frequently, beeping each time. This gets annoying after a while, so when charging using a USB car charger, I usually don't try to work at the same time as it still pulls the battery down. It'll last longer than without the charger since you are supplying some power, but it'll still eventually run the battery down.

Starlink Mobile

While I'm used to working fully offline for extended periods, I recently add the new Starlink Mobile to my truck. This is useful because it opens up a whole new way of working in the field. This trip I've been remotely logging into my home office and starting CPU hungry, long running conflation processing. This way when I get home, I'll have days of data already processed. Good conflation is not fast…

In the past I'd find rural libraries, since they all have free wifi. Many have limited hours though. Sometimes it's password protected, and sometimes it's not. Sometimes it's powered on when the library is closed,and sometimes not. So this isn't reliable. In areas I've mapped before, I often know those few remote places where I can get a decent cell connection. And I do have a cell booster wired into the spare power system too. But now I can work reliably (this was a work-cation) from my nice campsites, which lets me stay for a few days if I want.

I carry the mini in a hard-shell plastic case, cause I think it'd get destroyed if I left it loose. Or stolen. The case also has room for a variety of power options, since experimenting with those is part of the

plan. It only take me a few minutes to setup, and most of that is waiting for the antenna to be properly aligned.

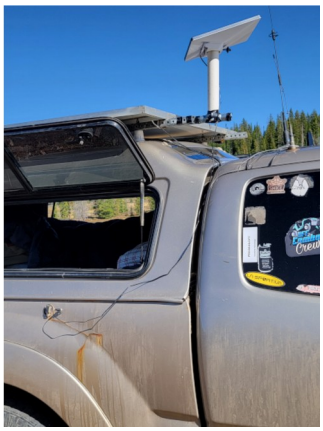
Powering From 12DC

Powering the Starlink off of a 12VDC battery doesn't work by default. The minimum I've ever gotten it to work is at 19VC using the same charger my laptop uses. The wire gauge and wire length is a big issue due to voltage drop over DC. Even with a short cable, I could never get my Starlink Mini to boot on just just 12VDC.

By default, the Mini comes with a 15m long cable. Nice if you need it that far away to find a sunny spot, but this is why it needs more power than 12VDC. I've been using a 2m cable of decent gauge, which is long enough for either the two mounts. As long as I'm camping where I get sun on the panels, I don't need the long cable.

I also found that the 19VDC step-up transformer I use for my laptop won't power the Starlink Mini, even with the short 2m cable. 24VDC appears to be the minimum needed.

Step Up Transformers



I'm currently powering my Starlink off of a 12V-24VDC step up transformer hard-wired directly into the solar power system in the back of my truck. I added a panel mount 5.5mm/2.1mm female connector to my truck bed. I plug a short 2m (6ft) cable and it works fine.

Since transformers suck power even if the device they are powering is turned off, I wired mine though a double-throw switch, so I can completely disconnect it from the power system.

Antenna Mounts

The Starlink Mini comes with two adapters for mount it. The default is the little tripod ground mount. I had a problem with this when some ATV idiots decided to drive through my campsite, and almost ran-over the antenna on the ground. Other than avoiding idiots, the ground mount works fine, even with the short cable. It's really easy to swap mounts, so I carry both,

Pole Mount

One of the included adapters is for the top of a 2" pole. I home-brewed one out of an old repeater antenna mount I had lying around, and cut a short piece off some 2" PVC I had in the scrap pile. The mount is bolted to the supports for the PV panels. The first version of this all the bolts kept vibrating loose on **smoothness=very_bad** roads. Now it's updated to be more robust, and is my preferred mount as it keeps it out of the way. I think in the winter, it'll be necessary to keep it out of the snow.

Ground Mount

The ground mount is a small triangular mount. Even with the short power cable I haven't any problems. I was worried being that close to my truck would be a problem, but so far it hasn't been.

Antenna Alignment

Aligning the antenna is pretty easy using the Starlink app. Once it powers up and the app can connect, it’ll search for satellites for a few minutes. Once the antenna gets it’s orientation, it’ll guide you to rotating the antenna to get online. If you camp in the same spot, you can connect to the wifi while it’s still doing orientation cheeks, since it’s already aligned. That’s useful if you only need a few minutes of connectivity to download email, a forgotten file, or a quick web search.