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16. ABSTRACT

Reliable high-bandwidth rural communications have been a significant challenge since early Intelligent Transportation Systems (ITS) deployments by the California Department of Transportation (Caltrans). There is an effort to install fiber-optic broadband services on select rural highways throughout the state; however, it will take years before the service is useable. Further, the service won't be installed on every rural state highway and will be located in areas highly susceptible to damage from wildfire, floods, and landslides. Reliable communications are critical to the reliability of ITS elements for the traveling public. ITS elements cease to function as intended when communications systems fail, which poses a problem in rural areas where ITS elements are deployed to mitigate the effects of non-reoccurring congestion due to snow, fire, floods, and other major incidents. Most rural Caltrans field sites selected have been impacted by the lack of available high-bandwidth communications options. These ITS field sites include infrastructure related to changeable message signs, video sites, and roadside weather information systems. Caltrans needs to find an alternative, reliable high-bandwidth wireless communications option that is less susceptible to weather-induced incidents. The Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center procured, installed, operated, and evaluated five SpaceX Starlink satellite broadband communication services for various ITS elements in Caltrans District 2. This research evaluated the procurement, construction, installation, integration, operation, and maintenance of the five selected rural sites. This interim report documents Starlink procurement issues.

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Advanced Highway Maintenance and Construction Technology Research Center

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University of California at Davis

SpaceX Starlink Satellite Broadband Communications for ITS: Procurement Issues

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Ty Lasky: Principal Investigator

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List of Acronyms and Abbreviations

| Acronym | Definition |
|----------------|--|
| ACH | Automated Clearing House |
| AHMCT | Advanced Highway Maintenance and Construction Technology Research Center |
| ATIRC | Advanced Transportation Infrastructure Research Center |
| Caltrans | California Department of Transportation |
| CCTV | Closed-Circuit TV |
| CMS | Changeable Message Sign |
| CVV | Card Verification Value |
| DOT | Department of Transportation |
| D2 | District 2 |
| DRISI | Caltrans Division of Research, Innovation and System Information |
| EMP | Electromagnetic Pulse |
| HP | High-Performance |
| IP | Internet Protocol |
| IPv4 | Internet Protocol version 4 |
| ITS | Intelligent Transportation Systems |
| OD | Outer Diameter |
| PM | Project Manager |
| PoE | Power-Over-Ethernet |
| RV | Recreational Vehicle |

| Acronym | Definition |
|----------------|---------------------------------|
| RWIS | Road Weather Information System |

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Chapter 1: Introduction

Problem

Reliable high-bandwidth rural communications have been a significant challenge since early deployment of Intelligent Transportation Systems (ITS) at California Department of Transportation (Caltrans). There is an effort to install fiber-optic broadband services on select rural highways throughout the state; however, it will take years before the service is useable. In addition, the service won't be installed on every rural state highway and will be located in areas highly susceptible to damage from wildfire, floods, and landslides. Reliable communications are critical to the reliability of ITS elements for the traveling public. ITS elements cease to function as intended when communications systems fail. This poses a problem in rural areas where ITS elements are deployed to mitigate the effects of non-reoccurring congestion due to snow, fire, floods, and other major incidents. Most rural Caltrans field sites selected have been impacted by the lack of available high-bandwidth communications options. These ITS field sites include infrastructure related to changeable message signs (CMS), closed-circuit TV (CCTV) video sites, and road weather information systems (RWIS). Caltrans needs to find an alternative, reliable high-bandwidth wireless communications option that is less susceptible to weather-induced incidents.

Objectives

The Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center proposed to procure, install, operate, and evaluate five [SpaceX Starlink \(https://www.starlink.com/\)](https://www.starlink.com/) satellite broadband communication services for various ITS elements in Caltrans District 2. This project is evaluating the procurement, installation requirements, integration, operation, and maintenance of five selected rural sites. The evaluation plan originally included three types of Starlink system as shown in Table 1.1.

Table 1.1: Starlink systems – initial plan

| System | Data speed category | Location | Device Cost | Quantity |
|--------------------|----------------------------|-----------------|--------------------|-----------------|
| Residential | 1x | Fixed | \$599 | 2 |
| RV | 1x | Mobile | \$599 | 2 |
| Business | 2x | Fixed | \$2,500 | 1 |

As will be discussed in Chapter 2, the RV system was eliminated from the evaluation at the procurement stage due to limited commercial and government access. By March 2023, AHMCT procured and tested the performance of one Business and one Residential service in three sites: Redding Fiber Hub, Sims Road, and Lassen Park. The fixed Business system was tested at the Redding Fiber Hub, while the Residential with mobility added was tested at the two field sites. After the first site visit and initial connection testing, AHMCT confirmed it would proceed to procure the remaining devices to yield one core system and four field systems (five total) for further testing.

This interim report elaborates on the details of system procurement, the issues identified during Task 2, and the updates made to the initial proposal plan for Task 2. One of the issues encountered in 2022 was the lack of availability and map coverage in some of the rural sites and all towns/cities. This issue was resolved in April 2023 when Starlink introduced bandwidth changes, i.e., limiting the bandwidth of Residential and RV users of the Standard Rectangular kit. At that point in the research, Starlink terms prohibited use of the RV system for commercial or government use. In addition, the Residential and RV systems did not provide a public internet protocol (IP) address. The panel decided the Residential system was not suited for Hub or field sites.

In Chapter 2, we discuss how the original plan in Table 1.1 changed to the list of devices and services in Table 1.2 by September 2023. Primarily, Starlink offered a new hardware called the “flat high-performance (HP) kit”, which is similar to the old HP kit (offered for business service) but without any need for tilting towards satellites. The flat panel HP kit achieves this due to use of phased-array antenna and maintaining more simultaneous satellite connections compared to the old HP kit. This hardware offering was followed by several changes of services and terms of use.

Table 1.2 presents the new procurement plan in which four flat HP kits and one HP kit (which is the same as the previous Business kit) would be used with a

fixed-location Priority service (rather than Mobile Priority service) for the entirety of the pilot test. These changes are further elaborated in Chapter 2.

Table 1.2: Starlink systems procured for pilot test – updated plan (September 2023)

| Kit | Service | Bandwidth | Mobility | Device Cost | Quantity |
|--------------------|----------------|------------------|-----------------|--------------------|-----------------|
| HP kit | Priority | High | Fixed | \$2,500 | 1 |
| Flat HP kit | Priority | High | Fixed | \$2,500 | 4 |

Chapter 2:

Starlink Procurement Process

Removal of Starlink Residential and RV Services from Procurement and Evaluation

As shown in Table 1.1, the original plan was to evaluate the Residential, RV, and Business services. There were two main reasons for removing Residential and RV services (and subsequently the Standard Rectangular kit) from evaluation:

- I. Starlink RV availability for commercial and government use
- II. Starlink public IP policy.

During the procurement investigation, AHMCT reviewed the Starlink Terms of Service in December 2022. Because this evaluation may lead to deployment, the terms (which are frequently updated) are important to Caltrans. During the procurement investigation, a key clause was identified under Section 6, "Starlink for Recreational Vehicles (RVs)":

"6.3 Limitation and Requirements for RV Users. Starlink for RVs is a consumer product only and is **not available for purchase or use by commercial, enterprise, governmental or institutional users**. Starlink for RV can only be used within the same continent as the registered shipping address."

The emphasis beginning "not available" was added here by AHMCT. This clause prohibited use of Starlink RV system by UC Davis and more importantly, Caltrans. Based on this indication, AHMCT consulted the project manager (PM) and the project panel in January 2023. AHMCT subsequently removed the RV system from the evaluation.

Since Residential and RV services lacked static public IP, they were removed from the evaluation. The panel decided that AHMCT will only focus on the Business service, which was broken down to Priority and Mobile Priority services in April 2023. As of September 2023, Residential and Roam/Mobile services only have a "Default" IP option, which does not offer any public IPv4 for customers.

Starlink Terms of Service evolve regularly. By September 2023, the above-mentioned Clause 6.3 had been removed. In fact, all Starlink services are now available for commercial use. The current terms of use that are significant for UC Davis and Caltrans are:

“5.3 Limitations on Mobility Services. Supplemental customer support for enterprise, institutional or government specific requests (e.g., modified invoicing or tax-exempt certifications) is only available under Starlink’s Mobile Priority Service Plans and not the Mobile Service Plans. Starlink does not guarantee when or where Starlink Mobile or Mobile Priority Services will be available.”

“8.5 Modifications to Starlink Products & Export Controls. Starlink Kits and Services are commercial communication products. Off-the-shelf, Starlink can provide communication capabilities to a variety of end-users, such as consumers, schools, businesses and other commercial entities, hospitals, humanitarian organizations, non-governmental and governmental organizations in support of critical infrastructure and other services, including during times of crisis. However, Starlink is not designed or intended for use with or in offensive or defensive weaponry or other comparable end-uses.”

Portability Option

Up until April 2023, there was a portability option that would effectively convert Residential to RV service.

“Enabling Portability. Portability allows you to relocate your Kit and access Services (“Portability”) at locations outside your registered Service address on your account (“Secondary Location(s)”), within your continent. You can enable the feature via your Starlink account for an additional monthly fee. You will be charged the additional fee on your next monthly invoice, in full monthly increments, which cannot be pro-rated. If you have multiple Starlink, Portability must be enabled and purchased for each Service address. The Portability feature and billing charges will be ongoing until you disable the feature via your Starlink account.”

Adding the portability option would add \$25 to the monthly fee for each device. AHMCT made use of this portability option in the first site visit and initial connection testing at Sims Road and Lassen Park. The portability option has since been removed and is no longer offered by Starlink.

Reserve Equipment

AHMCT is providing several spare kits and components to Caltrans, so they are available if needed for the pilot testing. These kits and components are not part of the planned pilot testing.

There are no plans to use the purchased Standard Rectangular kit for the pilot test. Under the new Starlink terms, one can subscribe to a priority service and take advantage of Standard Rectangular kit for commercial use. Although

subscribing for priority data removes the bandwidth restriction applied to Residential and Roam services, HP kits are expected to perform better than the Standard Rectangular kit with similar service due to their hardware advantages. As such, AHMCT has delivered and plans to transfer the ownership of the single Standard Rectangular kit that was purchased in October 2022 to Caltrans. Additionally, on October 16th, AHMCT delivered one extra HP kit and one extra flat HP kit to the customer as reserves for the five kits that were installed and will be field tested beginning October 2023. All three reserve kits will remain inactive (paused service) until further notice.

Alongside the three noted kits, AHMCT delivered an extra set of ethernet adapter, surge protector, ground pole, flat HP antenna cable, wedge mount and pipe adapter to D2 as spare parts for contingency during the pilot test.

Updated Procurement Plan Upon Starlink Change of Services

The biggest reason for changing the initial plan was the major change in services at Starlink. In April of 2023, Starlink updated the list of offered services significantly, introducing a new flat HP kit which enables users to access Starlink satellite internet in a truly mobile sense on moving vehicles and boats.

A new high-end service, called Mobile Priority, immediately became available for commercial use at the launch of Starlink flat HP antenna. This service was different from the RV service, which only added portability to the service address and allowed customers to use the Starlink standard rectangular antenna to access the internet at any location with satellite coverage while stationary.

After the change of services in April 2023, Starlink allows pairing hardware and services as presented in Table 2.1. By June 2023, AHMCT collected this new information and discussed the options for procurement with the panel, with focus on the necessity of public IPv4 for Caltrans application. It was then decided that AHMCT should perform initial testing at their shop, the Advanced Transportation Infrastructure Research Center (ATIRC), to confirm the feasibility of using HP and flat HP kits for the purpose of this project, i.e., establishing secure connection between Caltrans rural hubs and CCTV stations.

One recent change made to Table 2.1 is the addition of priority services that Starlink started to offer in September 2023 to pair with the Standard Rectangular kit. This facilitates the use of cheaper hardware for D2's application as priority services have no bandwidth restrictions and offer public IPv4. However, the Standard Rectangular antenna remains inferior to HP antennas in establishing satellite connections, and its power supply is not separate, so one cannot bypass the Starlink Wi-Fi router (powering the Standard Rectangular antenna) as easily as for HP kits.

Table 2.1: Available Starlink kits and services after April 2023 change of terms and services (updated in September 2023)

| Kit/Antenna | Available Services | Mobility | Public IPv4 | Priority Data | Bandwidth |
|--|---------------------------|---|--------------------|----------------------|---|
| Standard Rectangular (Tilts towards North to establish satellite connection) | Residential | Stationary with fixed service address | No | N/A | Limited download and upload speed. |
| | Roam (Mobile) | Stationary without service address and available anywhere with capacity | No | N/A | Unlimited standard data. |
| | Priority | Stationary with fixed service address | Yes | Yes (for x price) | No restriction on bandwidth with priority data. |
| | Mobile Priority | Stationary without service address available anywhere with capacity | Yes | Yes (for 5x price) | Location, weather, area capacity, and quality of antenna in establishing satellite connections will define the bandwidth. |
| High-performance (Tilts towards North to establish satellite connection) | Priority | Stationary with fixed service address | Yes | Yes (for x price) | Capped to Standard Residential bandwidth after priority data ends. |
| | Mobile Priority | Stationary without service address available anywhere with capacity | Yes | Yes (for 5x price) | |
| Flat high-performance (Doesn't tilt, can connect with much limited view of the sky) | Priority | Stationary with fixed service address | Yes | Yes (for x price) | Unlimited standard data. |
| | Mobile Priority | Mobile, i.e., on the moving vehicle/boat without service address and available anywhere with capacity | Yes | Yes (for 5x price) | Additional priority data available to purchase in the middle of period either by upgrading the plan or subscribing to \$2.00 per GB priority data option. |

In September 2023, AHMCT confirmed that one HP kit (for Redding Fiber Hub) and four flat HP kits (for Sims Road, Lassen Park, SR70-SR89, and Buckhorn CCTV stations) would be used for the pilot test as presented in Table 1.2. In October 2023 at the time of installations, Buckhorn was replaced by Cedar Pass due to construction. To guarantee service addresses and to save on costs, AHMCT will switch all devices to Priority service for the duration of the pilot test. There are several reasons for not making use of Starlink Mobile Priority service that can be activated on either kit:

- The Priority plan guarantees a service address unlike Mobile Priority, which is important as the ever-increasing customers pool added to the California area may eventually take satellite coverage beyond capacity.
- The pilot test is not expected to require any transfer of devices after installation.
- The Priority plan offers higher priority data with significantly less costly subscription plans compared to the Mobile Priority service.
- There are no technical differences between the two services except for where they are permitted to connect to the internet.
- Initial testing at AHMCT in August 2023 confirmed that both services are technically feasible for the pilot test and beyond as they both offer public IPv4 to be used for secure tunneling with Caltrans D2 routers.
- There is no difference in speed or bandwidth policy between the two priority services.

Guidance on the Starlink Online Procurement Process

Below are the screenshots for the step-by-step ordering of Starlink for the test site identified by Caltrans as Redding Fiber Hub. As specified in Table 2.1 the Priority (Business) service requires a specific **Service Address** to check for availability and to initiate ordering. Note that the Starlink website recommends the service address from its directory based on customer suggestion. This suggestion often includes the name of road/street, a county/town, and a state. It can be a bit troubling to specify an acceptable service address that covers rural sites. Fortunately, there is no need to specify an accurate location for Starlink to allow connection. These addresses cover a large area on highways.

For example, the following are identified as appropriate service addresses for the sites used in the pilot test:

- Redding Fiber Hub/40° 35' 11.04" N 122° 21' 43.66" W: Cascade Wonderland Hwy, Redding, CA, USA

- Sims Road CCTV/41° 4' 41.83" N 122° 21' 21.38" W: Cascade Wonderland Highway, Castella, CA, USA
- Lassen Park CCTV/40° 32' 41.42" N 121° 34' 38.89" W: 44 Manzanita Lake Campground Road, Shingletown, CA, USA
- Cedar Pass CCTV/41°33'37.6"N 120°17'14.7"W: CA-299 Alturas CA 96101, USA
- SR70-SR89 CCTV/40° 2' 19.58" N 120° 59' 1.47" W: 23990 CA-70, Twain, CA 95984, USA

The steps of ordering process from the start screen to the final order page are provided in Figures 2.1 to 2.6. Where needed, clarification and emphasis are provided for each step. These steps are as of September 2023, and subject to change by Starlink.

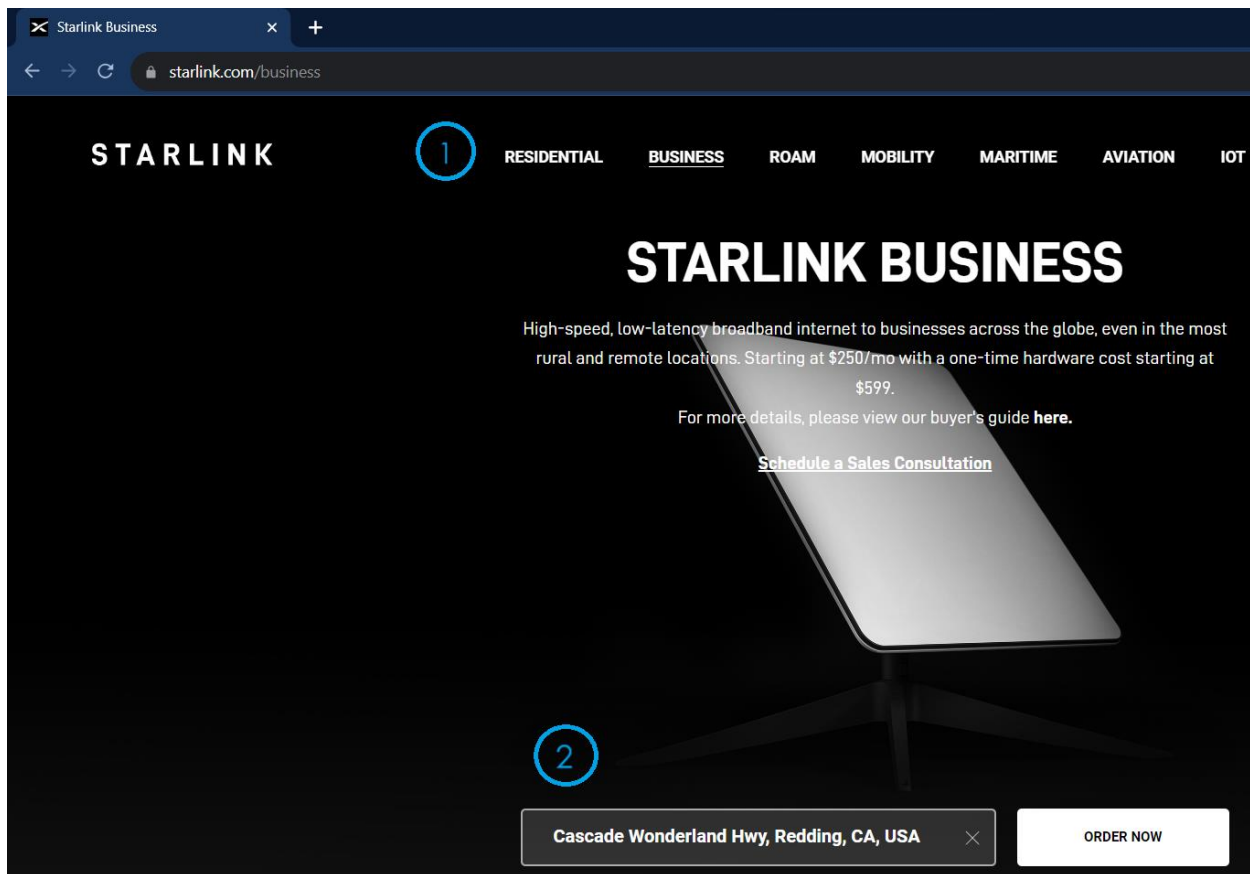


Figure 2.1: Starlink procurement Step 1: Starting page for service address and service type

The order page and process has changed slightly since the beginning of the project up to September 2023. The first step is to click on the correct tab on the home page. For ordering Priority service, one needs to make sure they are on the “Business” tab, while to order Mobile Priority the “Mobility” tab must be

selected. After confirmation of service address and clicking on “Order Now”, Starlink will confirm the kit and its price on the second page. Figure 2.1 shows the Starlink home page as the initial ordering screen. On this page and subsequent screens, key points are indicated by the light blue numbered circles. For this screen, at #1, choose the service type, in his case Business. At #2, enter the service location. Then, click “Order Now”, which leads to the screen in Figure 2.2.

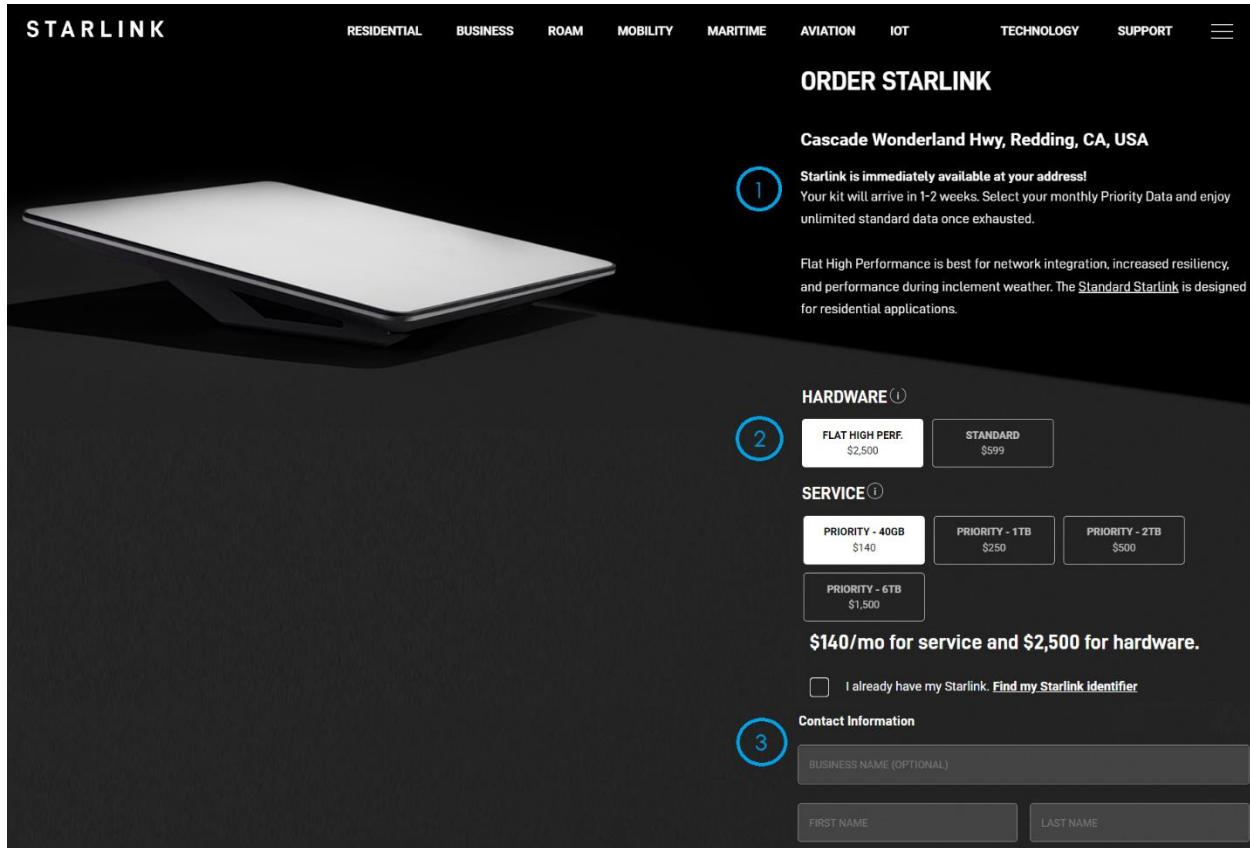
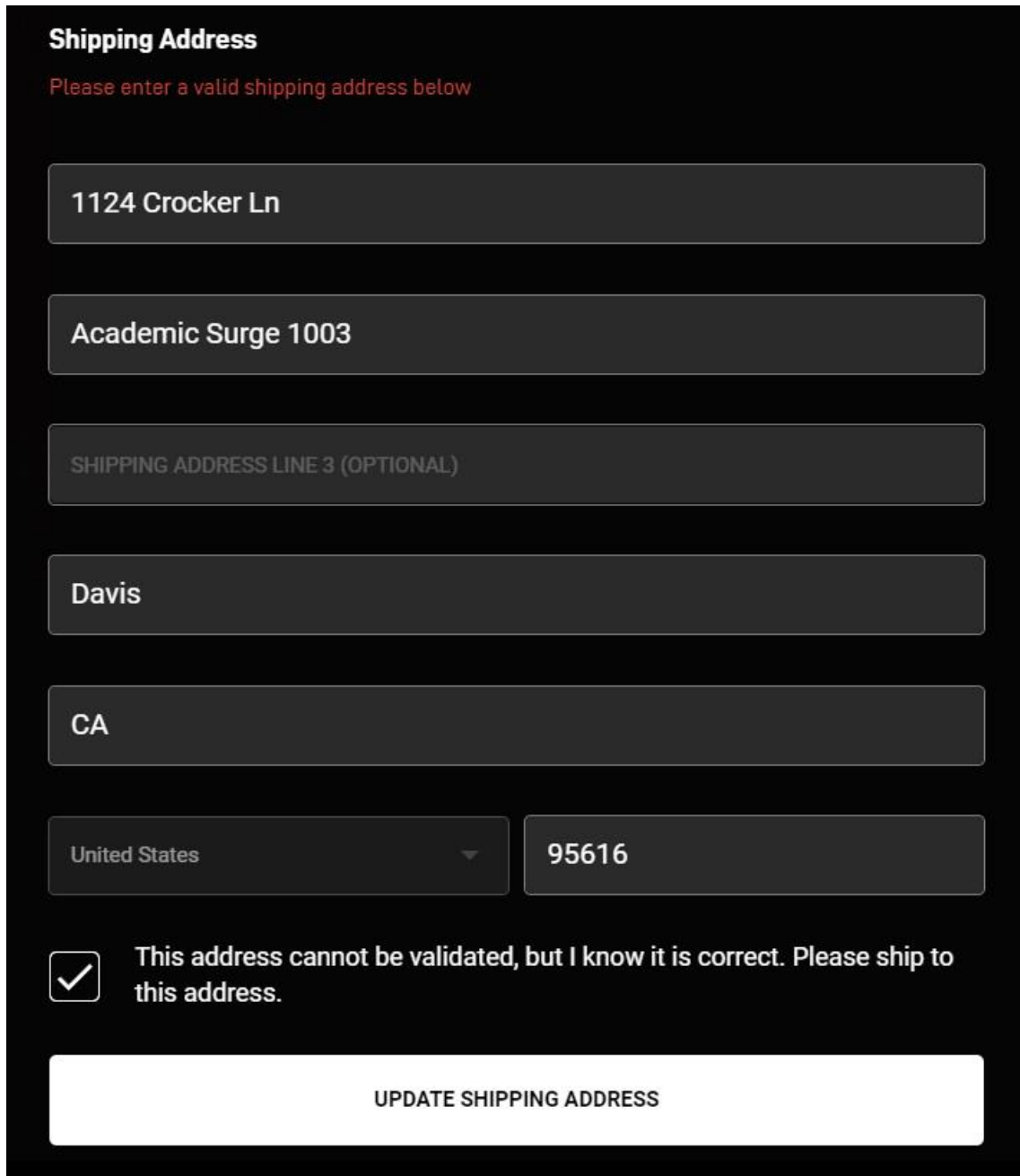


Figure 2.2: Starlink procurement Step 2: Starlink service availability, hardware, and service indications, and contact entry

Figure 2.2 provides Starlink service availability, indications, and contact entry. Here, the screen shows the selected location, followed by #1, which provides critical information about service availability. In this case, the service is immediately available, the ideal scenario. Other indication could be: (a) service is unavailable; or (b) you will be in a queue to receive service. Other indications may be possible. The buttons at #2 show the types of kits and services available. Here, both Standard and Flat HP kits are available. Starlink allows customers to match different services with different kits from the order page. After the order is placed, the service can be changed at any point from the Starlink account (depending on the selected kit), but the kit itself is only replaceable for thirty days in cases when an incorrect kit was selected. At #3,

enter the contact information for the service. This contact may be different than the purchaser information, which is entered in a subsequent screen.



Shipping Address
Please enter a valid shipping address below

1124 Crocker Ln

Academic Surge 1003

SHIPPING ADDRESS LINE 3 (OPTIONAL)

Davis

CA


United States ▼ 95616

This address cannot be validated, but I know it is correct. Please ship to this address.

UPDATE SHIPPING ADDRESS

Figure 2.3: Starlink procurement Step 3: Shipping address for the Starlink hardware

Figure 2.3 shows the entry form for the shipping address for the Starlink hardware. This address may be different from the service location. Provide the valid shipping address to receive the shipment. If automatic validation of the address does not work, carefully confirm the address and then click the check box noting the address is correct.

Shipping Address 

1124 Crocker Ln, 1003 Academic Surge
Davis CA 95616
US

Billing Information **1**

Card **ACH**

NAME (AS IT APPEARS ON CARD)

BILLING ZIP / POSTAL CODE


2 CARD NUMBER

MM YYYY CW

Figure 2.4: Starlink procurement Step 4a: Billing form for credit card payment

Figure 2.4 shows the billing form for credit card payment. The form will repeat the shipping address you have entered. It then includes two payment options at #1, credit card and Automated Clearing House (ACH), i.e., a direct charge to a bank account. In Figure 2.4, credit card is selected. The key information for credit card is the card number, expiration, and Card Verification Value (CVV). For a typical state Department of Transportation (DOT), the information here will need to be for an authorized credit card purchaser. The purchaser will typically not be the contact or the user of the system.

Figure 2.5 shows the entry form for the bank account ACH option. AHMCT has no experience with this approach. It may apply for some DOTs, but as with the credit card approach, only an authorized ACH purchaser can use this option, and the purchaser will typically not be the contact or the user of the system. Where ACH is applicable, the key information will be #1 routing number and #2 account number.

Shipping Address 

1124 Crocker Ln, 1003 Academic Surge
Davis CA 95616
US

Billing Information

Card ACH

ACCOUNT HOLDER NAME

1 ROUTING NUMBER

CONFIRM ROUTING NUMBER

2 ACCOUNT NUMBER

CONFIRM ACCOUNT NUMBER

Figure 2.5: Starlink procurement Step 4b: Billing form for ACH payment

| | |
|--|--------------------|
| Service | \$140.00/mo |
| Hardware | \$2,500.00 |
| Shipping & Handling | \$50.00 |
| Tax | \$184.88 |
| DUE TODAY | \$2,734.88 |
| PLACE ORDER | |
| <p>By placing this order, I agree to the Starlink Terms Of Service and Privacy Policy. You can cancel the recurring payment at any time via your Starlink Account. Starlink may update its Service Terms and pricing as needed after providing the required notice to you.</p> | |

Figure 2.6: Starlink procurement Step 5: Starlink order summary including initial and on-going charges

Figure 2.6 shows the Starlink order summary, including initial and on-going charges. The initial charge includes the first month service payment (here \$140), plus all up-front hardware, shipping & handling, and tax. The selected payment method will also be billed each month for the recurring service charge. This screen also includes a link to the Starlink Terms and Conditions and Privacy Policy. Review is recommended. The screen shown in Figure 2.6 is the final section of the ordering page. Upon clicking “Place Order”, the order will be submitted, the charge will be made, and Starlink will ship hardware within one to two weeks.

Service Availability, Policy, and Pricing Updates

Since SpaceX Starlink is a fairly new and dynamic company, it did not, at the time of evaluation, have all business aspects firmly established as a more seasoned company typically would. This gap was apparent in the service availability, policies, and pricing fluctuations during the study period.

In procuring the five systems for the evaluation, the researchers had to carefully check availability at the time of each system procurement. Sites were checked early in the procurement planning and selected in part for their

availability. As final procurement approached, availability was checked again, and sometimes service was no longer available. Typically, this is due to popularity of the service in the given area, and limited bandwidth availability. If you have a guaranteed service address in an area, you will not lose it as the area gets crowded, but new users may not be able to get in. Thus, it is critical to check availability at time of purchase and to procure service in a selected area as soon as you are certain you would need it.

Due to the primary mission of Starlink, the service is generally unavailable in more populated areas. The company is focused on providing service in underserved regions. Service availability in populated areas began increasing to a degree in the later part of this project.

Starlink is also prone to update policies fairly often. In the period of this evaluation, up to this report date, the team saw a few updates. Nothing was prohibitive to DOT use of the system, but it is important to be aware of the likelihood of such updates.

Pricing is also somewhat in flux and can change within a service period. DOTs would need to allow for some pricing uncertainty during the period of their contract.

Surge Protection

For surge protection, AHMCT ordered five units of Polyphaser Outdoor Twisted Pair Lightning Surge Protector model IXG-05 made for a four-pair power-over-ethernet (PoE) line with ground connection. This lightning surge protector/arrestor will help protect Caltrans equipment from surges in power that can be caused by lightning and other strong changes in electricity. The dataline twisted pair surge protector product is manufactured for Gigabit Ethernet up to 100 Mb/sec, PoE Data Turn-On Voltage of 75 VDC and used to protect sensitive electronic equipment.



Figure 2.7: Polyphaser surge protector IXG-05

Mounting and Installation

In this section, we focus on introducing all mounting equipment used for the pilot test installation planned for October 2023. AHMCT is designing an integrated HP pole mount for use at Caltrans installations. The design of this integrated mount will be documented separately. The mounting approach and hardware described below was procured and used for the project field testing.

In this plan, which works for both HP kits, we used a medium clamp with an extended arm and one set of crossover clamps to attach a pipe parallel to the CCTV pole or tower leg. Then we used a Starlink standard pipe adapter to mount the antenna on top of this pipe.

Table 2.2 lists all the equipment required for installation of each flat HP kit in addition to what comes with the flat HP kit and Caltrans routers and Omnitron switches.

Table 2.2: Starlink updated mounting solution for each flat HP kit used in the pilot test with its overall cost estimate

| Equipment | OD x Length | Qty | Price/Unit | Total |
|---|---|-----|------------|--------------|
| Trylon/accessories SAS300L, medium backing fits | 2 3/8" x 3' arm 4 1/2 " - 6" clamp | 1 | \$175 | \$175 |
| SitePro1 Valmont crossover clamp SSCK | 1.5" - 3.5" clamp | 1 | \$50 | \$50 |
| Starlink flat HP pipe adapter | Suitable for pipes up to 2.4" outer diameter (OD) | 1 | \$120 | \$120 |
| 2" x 2' galvanized pipe or Starlink ground pole | 1.75-2" x 2' | 1 | \$75 | \$75 |
| Flat HP 25-m Starlink cable | 0.5" x 82' | 1 | \$165 | \$165 |
| Polyphaser outdoor twisted pair lightning surge protector model IXG-05 | N/A | 1 | \$190 | \$190 |
| Total | | | | \$775 |

The flat HP kit shown in Figure 2.8 comes with everything that the old HP kit had in its box plus a Wedge Mount kit (arrives in a separate box and can be used to mount the antenna on a flat surface). Both Starlink HP kits come with Starlink power supply, built-in Wi-Fi router, 8-meter Starlink (antenna) cable, 5-meter ethernet cable, 2-meter router cable, Starlink router & power unit AC power cables. We will need a 25-meter replacement Starlink cable to connect the antenna from the pole to Caltrans cabinets. This cable will be intercepted with surge protector for additional safety.



Figure 2.8: Flat HP antenna attached to the wedge mount

In addition to the kit, longer antenna cables, and the surge protector, installation requires the following equipment for mounting the antenna:

1. Tylon/Accessories SAS300L: 2 3/8" x 3' Single Arm Standoff with Medium Backing Kits, which fit up to 5 5/8" OD rounds and 6" (60°) angles or 5" (90°) angles. This item is hot-dip galvanized and weighs 22 lb. The Small Backing Kit weighs less but fits up to 4 1/2" OD round, which works for the tower leg but not the CCTV pole (with OD of 4 9/16").



Figure 2.9: Tylon/Accessories SAS300L with Medium Backing Kits

Small-fit standard clamps/U-bolts support poles up to 4 1/2" OD. For any poles or tower legs above 4 1/2" OD up to 6 1/2", one can use either medium or large backing fits, with medium backing fits providing better support. Our test sites have poles 4 1/2" - 5 1/2" OD. As such, medium backing fits were acquired. It is also essential that the mounting solution gives us between 2' to 3' offset/standoff from the pole/tower leg

depending on the surrounding area to allow for free movement of the Starlink dish.

2. SitePro1 Valmont SSCK: One set of hot-dip galvanized Crossover Clamp with 1.5" to 3.5" OD. This crossover clamp connects the Trylon/Accessories arm to the base of the Starlink antenna.



Figure 2.10: SitePro1 Valmont crossover clamp SSCK

3. Starlink Flat HP Pipe Adapter: Designed to attach to any pole with a max diameter of 2.4" (62 mm). Slide adapter over the top of the existing pole, fasten provided screws, and drop Starlink in. Requires Wedge Mount Kit that comes with Flat HP Starlink.

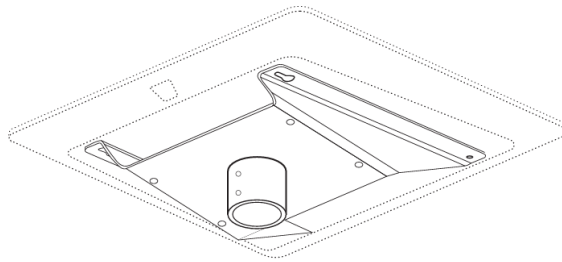


Figure 2.11: Starlink Flat HP Pipe Adapter attached to the Wedge Mount Kit, which is in part screwed to the bottom of the antenna

4. Finally, we need a 2" x 2' galvanized pipe to support the Starlink pipe adapter and the antenna on top. Alternatively, as a low-cost and easily available option, we use the Starlink Ground Pole which has 1.75" outer diameter plus six units of 1/4-20 x 1" flat countersunk head machine screws used to pressure fit the Starlink Flat HP Pipe Adapter to the bottom half of the pole. As showcased in the left image in Figure 2.12, the top half of this ground pole latches onto Starlink HP antenna without any adapter required, making this a viable solution for mounting both HP antennas.

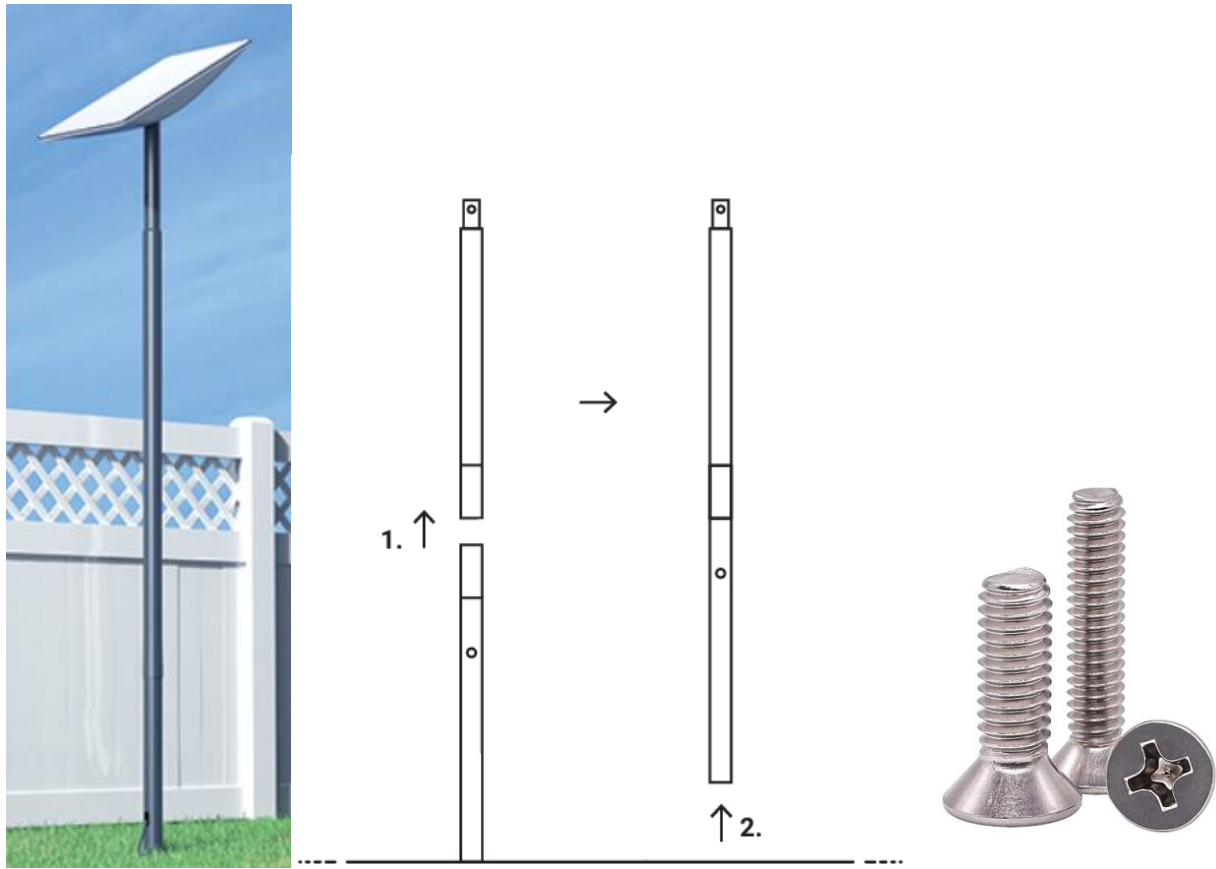


Figure 2.12: Starlink Ground Pole and 1/4-20 x 1" flat countersunk head machine screws

We used the Starlink ground pole connected to the flat HP pipe adapter and the wedge mount. For the HP kit it latches to the HP antenna without any adapter. We used the top half of the Ground Pole (approximately 3 ft) for the Fiber Hub installation. We used an approximately 1.5-ft section at each field site. Figures 2.13 through 2.16 provide views of the Ground Pole in various stages of installation in D2.



Figure 2.13: Starlink Ground Pole being installed at the Redding Fiber Hub



Figure 2.14: Starlink Ground Pole after installation at the Redding Fiber Hub



Figure 2.15: First view of a complete Starlink Ground Pole installation at a field site



Figure 2.16: Second view of a complete Starlink Ground Pole installation at a field site