Professional Capacity Building for Communications
Phase 5
Final Report

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1 List of Abbreviations

1xRTT	One Times Radio Transmission Technology
ADN	Advanced Digital Network
ADSL	Asymmetric Digital Subscriber Line
AM	Amplitude Modulation
ARP	Address Resolution Protocol
BRI	Basic Rate Interface
Caltrans	California Department of Transportation
CAT-5	Category 5
CAT-6	Category 6
CCTV	Closed Circuit Television
CDMA	Code Division Multiple Access
CHAP	Challenge-Handshake Authentication Protocol
CSU/DSU	Channel Service Unit/Data Service Unit
CMS	Changeable Message Sign
CO	Central Office
DCE	Data Communications Equipment
DDNS	Dynamic Domain Name System
DHCP	Dynamic Host Configuration Protocol
DS1	Digital Signal at Level 1 (1.544 Mb/s)
DSL	Digital Subscriber Line
DTE	Data Terminal Equipment
EDGE	Enhanced Data rates for GSM Evolution (or Global Evolution)
EIA/RS	Electronics Industries Association/Recommended Standard
EMS	Extinguishable Message Signs
ERP	Effective (or Equivalent) Radiated Power
EV-DO	Evolution, Data Only or Evolution, Data Optimized
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FTP	File Transfer Protocol
G	Generation (e.g., 4G is 4th Generation)
GHz	Gigahertz
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HAR	Highway Advisory Radio
HDSL	High bit rate Digital Subscriber Line
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
Hz	Hertz
ICMP	Internet Control Message Protocol
IEEE	Institute of Electrical and Electronics Engineers
IOS	Internetwork Operating System
IP	Internet Protocol
IPSec	Internet Protocol Security

ISDN	Integrated Services Digital Network
ITS	Intelligent Transportation Systems
ITSA	Intelligent Transportation Society of America
K	Kilobits per Second (e.g., 56k data rate), also kb/s
LAN	Local Area Network
LTE	Long Term Evolution
MAC	Media Access Control
Mb/s	Megabits per Second
MHz	Megahertz
MPLS	Multiprotocol Label Switching
MSU	Montana State University
NF	Noise Figure/Factor
OSI	Open Systems Interconnection
OSPF	Open Shortest Path First
OTDR	Optical Time Domain Reflectometer
PCS	Personal Communications System
PoE	Power over Ethernet
POTS	Plain Old Telephone Service (wireline telco services)
PPP	Point-to-Point Protocol
PPPoE	Point-to-Point Protocol over Ethernet
PRI	Primary Rate Interface
PTAP	Project Technical Advisory Panel
RF	Radio Frequency
RFB	Request for Bids
RIP	Routing Information Protocol
RSSI	Received Signal Strength Indication
RSTP	Rapid Spanning Tree Protocol
RWIS	Road Weather Information Systems
SLIP	Serial Line Internet Protocol
SME	Subject Matter Expert
S/N	Signal-to-Noise ratio
SNMP	Simple Network Management Protocol
SONET	Synchronous Optical Networking
SSH	Secure Shell
SSL	Secure Sockets Layer
TCP	Transmission Control Protocol
TDR	Time Domain Reflectometer
TKIP	Temporal Key Integrity Protocol
TMC	Transportation Management Center
TMS	Traffic Management System
UDP	User Datagram Protocol
VDSL	Very high bit rate Digital Subscriber Line
VPN	Virtual Private Network
WAN	Wide Area Network

WEP	Wired Equivalent Privacy
WiMAX	Worldwide Interoperability for Microwave access
WPA	WiFi Protected Access
WTI	Western Transportation Institute
xDSL	Digital Subscriber Line (of any type such as ADSL, HDSL, or VDSL)

2 Executive Summary

Under contract with the California Department of Transportation (Caltrans), the Western Transportation Institute at Montana State University researched and revised a comprehensive training curriculum for transportation communication systems that will build the professional capacity of rural intelligent transportation system (ITS) engineers and technicians. The project included a needs assessment working meeting and gap analysis, and the development and delivery of one training course. The principal deliverables of this project were the revised Curriculum Scope and Sequence (xii), a Needs Assessment and Gap Analysis (xi), an updated list of training providers (xiii), final materials from the training course, an evaluation of the training course, and a final report.

A Needs Assessment working meeting was conducted with Caltrans senior functional managers in each Caltrans district and some of the relevant offices at Caltrans Headquarters. Overall, the group confirmed that training for ITS data communications is important and of priority, now and in the future. Several of the higher priority needs for ITS data communications training are currently being met with the existing PCB courses. However, potential gaps open with challenges securing qualified subject matter experts to deliver on-site courses. The courses that have been developed and delivered through the project are perceived as useful, while the subjects and topics in the Curriculum reflect the state of the practice regarding ITS data communications.

The curriculum consists of six major subjects: Plant Wireless, Telco Wireless, Plant Wired, Telco Wired, Internet Protocol (IP) Fundamentals, and Small Data Center Design for Transportation Management Centers (TMC). During this project phase, the topics for Telco Wireless were condensed to combine legacy technologies and put more emphasis on later generation technology. The topic of 5G Wireless technology was added. The learning objectives for Network Security in the IP Fundamentals subject area were enhanced. And the topic of Serial Connectivity was removed from the Curriculum. Number of training days were adjusted accordingly.

After the Needs Assessment, the project focused on developing and procuring a training course in RF Fundamentals. A formal limited solicitation process was conducted to secure an appropriate training provider and deliver a course in *Radio Frequency (RF) Fundamentals Training*. A subject matter expert delivered 40 hours of training over five days. Course evaluations and Project Technical Advisory Panel (PTAP) observations indicated that the course was a success.

Considerable effort was put into researching and developing a list of potential training providers (formerly referred to as a Subject Matter Experts list) to ensure that the limited solicitation request for bids (RFB) reached the largest possible pool of qualified training providers, and ultimately to secure an excellent instructor considered an expert in the field. The research team also prepared alternative formats of this list to make it more user friendly and facilitate searches by subject matter. As companies and instructors come and go, this is a dynamic document and future work will necessarily include updating this list.

This project directed the development and evolution of a robust training curriculum that meets the needs of ITS engineers for professional capacity building in ITS communications. Technical, in-depth training courses taught by subject matter expert instructors have been delivered. These courses incorporate hands-on, practical, and relevant materials. The project has identified quality instructors and established content, process, and procedure for procuring additional training. In summary, this project has been

extremely successful in workforce development for mission critical skills in ITS communications. Its impact has been immediate and will last into the future.

3 Introduction

Rural Intelligent Transportation Systems (ITS) deployments are becoming increasingly complex in order to adequately address the challenges that rural transportation presents. A greater number and variety of field devices are being utilized to improve the safety and operations of rural travel. Design of communication networks between devices such as Highway Advisory Radio (HAR), Road Weather Information Systems (RWIS), Changeable Message Signs (CMS), Closed-Circuit Television (CCTV), Extinguishable Message Signs (EMS), roadway sensors, and the Transportation Management Center (TMC) that collects and responds to the information is a key factor in the successful implementation of such field devices. With any advancing technology, there is a need for a skilled workforce with an advancing skill set, which in turn requires ongoing training in new technologies.

To realize the full benefits of rural ITS on the transportation system, engineers as well as technicians must not only be aware of what technologies are available, but especially how to best select, implement, and maintain those technologies. Due to challenges presented by rural ITS communications, there is a clear need for an educational curriculum that addresses rural ITS communications engineering across the board with a hands-on approach. At the least, this curriculum should be designed to address underlying rural ITS engineering and design principles, available technologies, and practical applications for those technologies. To best present the curriculum the literature suggests it should be taught by subject matter experts who can bring their own experiences and best practices into the classroom.

Phase 1 (Caltrans Contract Number 65A0271) of this project identified subject areas and specific topics that Caltrans ITS engineers identified as training needs in ITS telecommunications (i, ii). Based on this assessment of need, a pilot course on RF (Radio Frequency) System Design was delivered in the first phase of the project. Again, based on the results of the needs assessment and guidance from the Project Technical Advisory Panel (PTAP), Phase 2 (Caltrans Contract Number 65A0403) of the project facilitated successful courses on Optical Fiber and IP Fundamentals (iii, iv, v).

Further review of the needs assessment and gap analysis conducted in Phase 1 of the project (i), along with input from the PTAP, substantiated the need to continue investigation and development of additional ITS communications training for Caltrans ITS engineers in a third phase of the project (Caltrans Contract Number 65A0500). The subject of Telco Wireless was chosen as the training focus for this phase and a course on Telecom Wireless Fundamentals was delivered. Additionally, since the original needs assessment and gap analysis were conducted in Phase 1, they were updated and repeated within Phase 3's project scope (vi). The curriculum scope and sequence were also revised based on development of the Telco Wireless course and results of the needs assessment conducted in Phase 3 (vii).

After the needs assessment and gap analysis conducted in Phase 3, as well as input from the Project Technical Advisory Panel (PTAP), a sixth subject was added to the curriculum during Phase 4 (Caltrans Contract Number 65A0606) of the project – Small Data Center Design for Transportation Management Centers (TMC). This phase of the project focused on developing and procuring training in data center design for TMCs. A formal limited solicitation process was conducted to secure an appropriate training provider and deliver a course in *Small Data Center Design, Structured Cabling, and Grounding.* A subject matter expert delivered 40 hours of training over five days. Course evaluations and Project Technical Advisory Panel (PTAP) observations indicated that the course was a success. The principal deliverables

of this project were the revised Curriculum Scope and Sequence (viii), an updated list of training providers (ix), final materials from the training course, an evaluation of the training course, and a final report (x).

Additionally, one of the research outcomes of Phase 4 was to demonstrate the viability of the developed procurement process and help transition the overall curriculum to a mainstreamed, internal Caltrans process. To date, six training courses have been developed and delivered through this project. Caltrans successfully utilizes those instructors and course content to procure additional training for ITS engineers.

Past needs assessments and training course evaluations substantiated the choice to further investigate new training courses in Phase 5 of this project. The research problems to be addressed in this study were that of evaluating training needs for ITS engineers and conducting a gap analysis for relevant training, determining the detailed content of prospective courses for ITS engineers, identifying suitable contractors to deliver the courses, and evaluating the courses. As these research problems fall within a larger curriculum for professional capacity building for communication systems, the scope and sequence of the curriculum was revised considering the results of the prior project phases and the needs assessment / gap analysis conducted during this project phase. One course was procured in the same manner used in the prior project phases – *Radio Frequency (RF) Fundamentals Training*.

Several deliverables were completed to address the proposed tasks of this project. The training course and evaluation summaries are included in this final report document. For the sake of clarity, the Needs Assessment and Gap Analysis report (xi), the revised Curriculum Scope and Sequence (xii), and updated Identified Training Providers List (xiii) have been left as stand-alone documents. Critical elements of these documents are included in this final report.

4 Background/History

To maintain the viability of the American transportation system as it is challenged by a smaller labor pool, higher and more intense demands, and limited resources, workforce development must be promptly and pro-actively addressed (xiv). However, the Framework for Workforce Planning, Development, Management and Evaluation as developed by the Transportation Workforce Development sector of the FHWA OPCD recognized in 2010 that a new generation of employees is emerging. This generation of workers brings a different set of priorities to the workplace. They "…grew up in the electronic age, [are] more comfortable with change, have greater expectations for job satisfaction, and are more willing to challenge and to be challenged" (xv). Their success in meeting the current challenges of the transportation industry "will depend to a great extent on the ability of employers to introduce the emerging workforce to new and innovative approaches in workforce planning and development" (xv). The Project Technical Advisory Panel (PTAP) suggested that with the loss of experience and skills due to staff retirements combined with the demand for new skills, agencies are refining core competency definitions and re-evaluating which should be maintained in-house.

Improving the safety and operations of transportation in often rugged and remote areas is a focal point for rural ITS installations. Designing and maintaining a reliable communications infrastructure to retrieve data from these sites is a challenge even for the most experienced engineer. As Caltrans states in their original description for this project (xvi):

> *"Understanding what communication technologies exist and how the underlying principles work will allow an engineer to design a communications network that will work reliably when needed most—during an incident. Often, because an engineer does not have the underlying knowledge of a communication technology, a less than reliable network is designed, often with undesirable results based on claims from a vendor or unrealistic expectations from technologies that were not designed to perform the task at hand."*

This lack of skill is partially the function of information existing in a multitude of formats from many different sources, with no one comprehensive and easily accessible resource.

Indeed, one overview for a college course offered in 1996 stated, "Ubiquitous access to information, anywhere, anyplace, and anytime, will characterize whole new kinds of information systems in the 21st Century" (xvii). Particularly in relationship to wireless communications and mobile information systems, the professor said, "There exists no well-defined body of knowledge that a student must learn to become proficient" (xvii). While this course was offered some years ago, these statements are still applicable today.

To address the challenges of rural ITS communications and the need for related professional capacity building, the project team proposed to develop a comprehensive training curriculum and deliver training for rural ITS communications. The remainder of this document describes the fifth phase of this project and its results.

5 Methodology

This project consisted of four tasks: *Project Management, Course Selection, Course Delivery,* and *Evaluation*. This section includes a summary of the methodologies used for each task. More detailed descriptions and plans can be found in the individual sections of the report and related deliverable documents which are referenced below.

Project management involved regular communication (in person, electronically, and by telephone) between members of the research team, the Caltrans project manager, and the Project Technical Advisory Panel (PTAP), as well as subject matter experts, course instructors, and vendor representatives. Project meetings were held as necessary to discuss the status of the project and address any issues or questions. Quarterly progress and financial reports were submitted by the research team to the Caltrans project manager. Project fact sheets were developed and shared. Documents and updates were posted to the website. This final report represents the completion of the project management task. Note: the PTAP and the research team worked closely to conduct the needs assessment and procure and deliver the coursework. Together, the group is referred to as the project team.

Task 2 *Course Selection* included selecting training topics, determining which courses would be procured directly by Caltrans and which would be procured through this project, developing a formal Request for Bids, and selecting an appropriate instructor (Subject Matter Expert) / vendor to deliver the training course(s). Since significant time had passed since the last needs assessment and gap analysis were conducted, the research team and the PTAP agreed that another needs assessment was warranted and important for directing this phase and future phases of the project. The project team reviewed past needs assessments conducted for this project and agreed that a different approach would be more appropriate for this project phase. (Note: the other needs assessments have been comprehensive online surveys.) To maximize data collection while being as efficient as possible, this assessment was an interactive working meeting facilitated live by the project team via WebEx. The research team analyzed the results and completed a gap analysis. Based on results of the needs assessment and gap analysis (xi), RF Fundamentals was selected for course development and procurement by the project team. Additionally, Caltrans procured and delivered several Optical Fiber and IP Fundamentals courses with the instructors who delivered the original courses during prior project phases.

The research team conducted a thorough search for training providers and available training opportunities that covered Radio Frequency (RF) Systems Fundamentals. Learning objectives for the proposed course were reviewed in the curriculum (xii) and refined for the training course. The research team identified contractors who could potentially deliver the course and were interested in doing so (Appendix A: List of Identified Training Providers – Radio Frequency (RF) Fundamentals Training). A limited solicitation and detailed Scope of Work were developed and approved. A Request for Bids (RFB) (Appendix B: Request for Bids) was posted and distributed, and bids were accepted. The responses were evaluated based on an approved scoring rubric and a training provider was selected and contracted.

The project team worked with the contracted training provider to customize existing course materials to meet the needs and expectations for the project. The project team also coordinated logistics and facilitated delivery of the course. *Radio Frequency (RF) Fundamentals Training* was delivered October 24–28, 2022, at the Sacramento Regional Transportation Management Center (TMC) in Rancho Cordova, California. The course was taught by Jonathan David with Aviat Networks.

Students completed evaluation forms and a member of the PTAP/project team attended the course. Evaluations and PTAP feedback were compiled and analyzed by the research team.

Finally, the project team identified next steps using the results from the project tasks, and input and feedback from the PTAP.

6 Curriculum Scope and Sequence

6.1 Curriculum Scope and Sequence Revision

Through a comprehensive literature review (ii) and a needs assessment (i) conducted with Caltrans engineers in Phase 1 of this project, five major subjects were originally identified as important knowledge and skill areas for successful rural ITS implementations. These subject areas are: Plant Wireless, Telco Wireless, Plant Wired, Telco Wired, and IP Fundamentals. A sixth subject area was added during Phase 4 of the project – Small Data Center Design for Transportation Management Centers. The curriculum scope and sequence is based upon these subject areas and includes descriptions, prerequisites, duration, method of presentation, and specific learning objectives. The target audience includes field engineers and technicians who apply ITS technologies in rural areas to improve transportation safety and operations.

The original curriculum scope and sequence developed in Phase 1 was revised in Phase 2 of the project based upon input from the Project Technical Advisory Panel (PTAP), and the development and evaluation of the two training courses delivered during that phase. In Phases 3 and 4, the curriculum was again revised based upon guidance from the PTAP, delivery of another training course in each phase, and feedback from a second needs assessment survey. In Phase 5 of the project, a third needs assessment was conducted, this time in the form of a working meeting with Caltrans senior functional managers, and district and office leadership. Guidance from the PTAP and the results of this needs assessment and subsequent gap analysis (xi) helped direct the curriculum's revisions during this phase of the project.

To reflect the evolution of wireless technology, a module on 5G Wireless Technologies was added to the Telco Wireless subject area. The older generation technologies (GSM, GPRS, CDMA, 3G) were condensed into one topic area – Telco Wireless Legacy Technologies – and time spent on the topic was reduced. The total days of training for Telco Wireless were reduced based on these adjustments. The topic of serial connectivity in the Plant Wired subject area was also removed and training time adjusted accordingly. And the topic of Network Security in the IP Fundamentals subject was further enhanced with additional learning objectives and another day of training recommended.

The research team felt it would be useful to have the scope and sequence available as a separate document. Therefore, to eliminate redundancy, the revised curriculum can be found in the document titled *Professional Capacity Building for Communications Curriculum Scope and Sequence, Revised for Project Phase 5* (xii). For quick reference, the subject areas and associated topics are outlined below. Also included are notes indicating the major changes to subject areas and topics as the curriculum evolved.

- Plant Wireless
    - Plant wireless core and RF system design
    - 802.11 (WiFi) and related
    - Microwave
    - Short haul radio
    - ~~Privately owned WiMax~~ (*removed in Phase 3*)
- Telco Wireless
    - Telco wireless core and cellular / PCS basics
    - Telco Wireless Legacy Technologies *(combined GSM, GPRS, CDMA, 3G in Phase 5)*
    - ~~GSM data, GPRS, 3G and Next Generations~~

  - ~~CDMA data, 3G and Next Generations~~
  - ~~Telco owned WiMax~~ (*removed in Phase 3*)
  - LTE (Long Term Evolution), 4G and Next Generations *(added in Phase 2)*
  - 5G Wireless Technologies (*added in Phase 5)*
- Plant Wired
  - Plant wired core / plant wiring basics
  - ~~Serial connectivity~~ *(removed in Phase 5)*
  - xDSL
  - Optical fiber
- Telco Wired
  - Telco Wired Core (*added in Phase 3*)
  - POTS
  - Analog data circuits
  - ISDN
  - xDSL
  - DS1/ T1
  - Fractional DS1/T1
  - Frame relay
  - MPLS (*added in Phase 3*)
- IP Fundamentals
  - Understanding IP networks / IP Networking Core
  - Local Area Networks (LANs)
  - Wide Area Networks (WANs)
  - Network security
  - Vendor specific equipment training (e.g., Cisco, Juniper, other)
- Small Data Center Design for Transportation Management Centers (*added in Phase 4*)
  - TMC Overview
  - Data center design short course for TMC managers
  - Data center design for TMC / ITS engineers
  - Site and facility tours

6.2 Identified Training Providers

In previous documentation, this compilation of potential training providers has been referred to as a Subject Matter Expert list. Without more in-depth assessment of a vendor's capabilities (i.e., through the RFB process or with similar rigor), it is difficult to judge whether a vendor is indeed a subject matter expert as defined by the PTAP. Thus, this list has been titled *Identified Training Providers, Professional Capacity Building for Communications (Phase 5)*. Because of its length and detail, the list is provided as a stand-alone document (xiii). The research team is also providing this list in a sortable format to allow filters for a specific subject (e.g., only showing vendors who can provide training in Telco Wireless technology). Caltrans, Montana State University, and the members of the PTAP and research team neither endorse nor disqualify any vendors on this list.

One of the core tenets for this project was to develop training that would be presented by experts in their field. As such, Phase 1 identified several potential vendors that could provide training in the ITS communications topics listed above. Phase 2 expanded the list with a particular focus on training offerings in plant wired and IP Fundamentals topics. During Phase 3, the list was again reviewed and revised focusing on Telco Wireless communications training providers. And in Phase 4, the list was reviewed and updated with those providers that offered training related to data center design and structured cabling. In this phase (Phase 5), the list was updated overall and with an emphasis on training related to RF Systems.

The list of identified training providers is dynamic. It includes but is not limited to, vendors and training providers that appear to have some or all the qualifications listed in the RFBs, including on-site course delivery, ability to customize content, hands-on exercises, and an established course(s) that addresses most of the expected learning objectives. The list was compiled through PTAP recommendations, word of mouth, recommendations from instructors, and an extensive web search.

The expertise of vendors that submitted a bid in response to an RFB was evaluated by the PTAP based on the approved limited solicitation scoring rubric. A provider was further vetted after a contract was signed and prior to course delivery. It should be noted that this list represents a best effort and that there may indeed be other possible providers not listed in the document. In turn, the procurement process is open and other qualified vendors are eligible to bid.

While the list of training providers focuses on vendors who provide training on the topics/subjects that were included in the RFBs, it also includes those who provide training on the topics that haven't yet been addressed with coursework in this project. They were included to more thoroughly address the overall curriculum and provide a starting point for consideration of future courses. Additionally, some vendors may provide training in these topics, but did not appear to meet one or more RFB requirements. For example, they may not provide on-site training. However, in the interest of thorough documentation, the research team felt it was important to still include these providers in the list. Note that these vendors were not evaluated to the same extent as those receiving the RFB and submitting a bid. Therefore, further due diligence would be necessary to consider them for contracting.

The updated Identified Training Providers list contains general and individual contact information for the different organizations. The vendors that received the formal Request for Bids (RFB) for each of the released limited solicitations are marked along with those who submitted a bid.

7 Needs Assessment and Gap Analysis

As noted above, the Needs Assessment and Gap Analysis report is a separate document (xi). An overview of the study and its conclusions are included here.

7.1 Overview – Needs Assessment and Gap Analysis

Needs assessments and gap analyses were conducted in Phase 1 (2009) and Phase 3 (2015) of this project. Because five years had passed since the last needs assessment, the PTAP and the research team agreed that another needs assessment was warranted and important for directing this project phase and future related work.

The project team reviewed the past needs assessments and agreed that a different approach/survey would be more appropriate for this project phase. (Note: the other needs assessments have been comprehensive online surveys.) The primary objective for this assessment was to identify and describe training that is most applicable to the ITS engineers and technicians in the field and directly working with ITS technologies.

This assessment also differed from past assessments in that it included all Caltrans Districts and relevant Offices versus focusing on primarily rural Districts where this project is based. The training courses developed through this project include content applicable to both rural and urban ITS applications and have since been procured and delivered around the state. Professional capacity building for ITS data communications is a relevant concern across the board.

To maximize data collection while being as efficient as possible, the assessment was an interactive working meeting facilitated live by the project team via WebEx. Data were collected through a pre-meeting survey, a working meeting and Mentimeter presentation, and a Top 10 survey. This needs assessment was designed to identify the training priorities for ITS data communications based on current and future project work being conducted. The goal was also to collect feedback on the training already delivered to help inform decisions about future training development and delivery. The results help quantify training needs and priorities; topics that are higher priorities for training were identified based on the rankings and the representative charts.

Senior functional managers in each Caltrans district and some of the relevant offices at Caltrans Headquarters were invited to participate in the working meeting. Participants represented Caltrans Districts 1, 2, 4, 6, 7, 8, 10, 11, and 12; Headquarters Maintenance; Maintenance TMS Asset Management; and DRISI.

7.2 Conclusions – Needs Assessment and Gap Analysis

The subjects and topics addressed in the Curriculum Scope and Sequence are complex and require study and experience over many years. The PCB courses are meant to provide basic training and familiarization of the identified technologies; significant study and effort over time is necessary for mastery of these complex subjects. It is important for Caltrans to consider building the professional capacity of staff members over time, not just with one-time classes.

Overall, the group said that training for ITS data communications is important and of priority. Training addressing IP Fundamentals topics is of highest priority both now and in the future. Training for optical

fiber and LTE technologies is of high priority as well. The group also indicated that data center design training for TMC / ITS engineers and training addressing core skills in all subjects were of importance.

Several of the higher priority needs for ITS data communications training are currently being met with the existing PCB courses. However, potential gaps open with challenges securing qualified subject matter experts to deliver on-site courses.

The subjects and topics in the Curriculum generally reflect the state of the practice regarding ITS data communications. However, the results of the needs assessment indicate that some of the older technologies could potentially be phased out of the Curriculum or training duration reduced. Similarly, some new topics and learning objectives could be added to the Curriculum to accurately reflect the current and future ITS data communications field.

The courses that have been developed and delivered through the project are perceived as useful. The PTAP has already acknowledged that the courses receiving relatively lower perceived usefulness scores need to be revised to better meet training needs. The *Hands-On Ethernet and TCP/IP Fundamentals* course is considered quite important based on current and future project work. The same can be said for *Telecom Wireless Fundamentals* and *Hands-On Advanced IP Networks / Protocols. Mastering Fiber Optic Network Design and Installation* was also rated important based on project work.

Finally, the interactive meeting format was well-received and garnered good responses and participation. The group agreed that it was a good use of time and appreciated seeing the real-time results to the survey questions.

8 Radio Frequency (RF) Fundamentals Training Course Delivery

To adequately address the diverse aspects of Rural ITS Communications, the project and the developed curriculum have been divided into different subject areas with associated topics. Plant Wireless Core and RF System Design are the first topics in the Plant Wireless subject area. RF Systems Fundamentals was the topic for the course procured during this project phase.

A course titled *Radio Frequency (RF) Fundamentals Training* was delivered at the end of October 2022. This section describes the design, content, delivery, and evaluation of this course.

8.1 Course Design

A solid foundational understanding of RF systems is essential for building successful wireless communication links. As an important first step, *Radio Frequency (RF) System Design* was the pilot course delivered in 2010 during project Phase 1 (xviii). However, that course did not meet the PTAP's and project's expectations for content and delivery. With that in mind, the process for procuring new coursework has been formalized and made more rigorous to help ensure high quality, practical, hands-on training from field experienced subject matter experts. The learning objectives for that pilot course were intentionally written broadly to cover basic knowledge of radio frequency communications and therefore remained unchanged for the training delivered during this project phase.

The research team conducted a thorough search for training providers and available training opportunities covering Plant Wireless core topics, specifically RF system fundamentals. The team also reviewed vendors previously documented as providing RF related training. Based on the results of this search and review, the research team identified potential contractors for this course. Caltrans, Montana State University, and members of the PTAP neither endorse nor disqualify any vendors on this list. (See Appendix A: List of Identified Training Providers – Radio Frequency (RF) Fundamentals Training.)

A limited solicitation and detailed Scope of Work for the course in Radio Frequency (RF) Systems Fundamentals was developed and approved. A limited solicitation Request for Bids (RFB) was posted and distributed, and bids were accepted. The responses were evaluated based on an approved scoring rubric – selection included factors other than cost. Aviat Networks was chosen to develop the course materials and deliver the training. Appendix B: Request for Bids includes the scoring factors and the detailed Scope of Work.

With input and review by the PTAP and the research team, draft materials were developed by the instructor Jonathan David. Final course materials were approved, and the course was delivered October 24-28, 2022.

8.1.1 Target Audience

The target audience includes field engineers and technicians who apply ITS technologies in rural areas to improve transportation safety and operations. Participants will generally be electrical engineers, electrical technicians, or other engineers with ITS design and implementation responsibilities.

8.1.2 Participant Prerequisites

Basic electrical engineering skills or relevant experience. Participants will generally be electrical engineers, electrical technicians or other engineers with ITS design and implementation responsibilities.

8.1.3 Method of Presentation

Instructor-led classroom and hands-on laboratory activities.

A minimum of 25 percent of in-class time will be dedicated to realistic, hands-on problem-solving and lab exercises, in addition to traditional classroom work.

8.1.4 Course Length

Five (5) days = 40 hours

8.2 Content

The research team and the PTAP reviewed the Plant Wireless Core and RF Systems Design learning objectives in the established Curriculum (viii) and considered results of the most recent needs assessment (xi). As noted above, the objectives were originally written broadly, and it was determined that they were still relevant and appropriate for this training. The objectives were included in the Request for Bids as required content for the course. It was expected that a contractor would enhance and customize an existing course based on the minimum objectives in the RFB and not develop a new course from scratch.

The approved outline for the RF Systems Fundamentals training follows.

Note: The text for Section 8.2.1 Course Title through Section 8.2.5 Equipment and Materials is taken from the approved Aviat Networks course outline, the final syllabus for the course, and the final RFB. Some formatting has been changed to fit the report document requirements.

8.2.1 Course Title

Radio Frequency (RF) Fundamentals Training

8.2.2 Course Description

Plant wireless communication, as applied to Rural ITS, consists of systems that are user owned and installed. Basic knowledge of radio frequency communication is necessary for designing and building successful wireless communication links. For example, with the availability of the 4.9 GHz Public Safety band, RF systems may be an important way to connect multiple ITS field elements to a Transportation Management Center (TMC).

After taking this course, ITS engineers and technicians will have the fundamental skills and knowledge necessary to design, implement, and maintain wireless communication links with RF technology. Students will understand and be able to apply microwave radio concepts, principles of system architecture, and microwave radio wave propagation, as well as the fundamentals of transmission engineering and data transport protocols. The course will be highly interactive with over 25% of instructional time spent on hands-on, realistic lab exercises.

8.2.3 Learning Objectives

After completing this course, the student will be able to:

- Define and explain terminology and general concepts for plant wireless communication systems.
- Compare equipment specifications for RF systems.

- Select appropriate equipment for the site and system requirements (e.g., filters, power dividers, combiners, directional couplers).
- Evaluate tower and antenna site requirements, including availability of existing towers, tower structure (e.g., self-supporting or guyed), and potential antenna sharing.
- Calculate a link budget allowing for RF power, bandwidth, bit error rate, and channel noise among other variables.
- Calculate system losses due to path, system, and obstructions (i.e., transmission line loss, connector losses, path loss, and/or combiner loss).
- Evaluate the effects of fading using statistical fading models and distance-power (path loss) relationships in different propagation environments.
- Calculate path-related impairment such as the effects of outdoor terrain and structures on signal propagation.
- Analyze antenna polarization mismatch and apply the Power Loss Factor.
- Determine and apply antenna parameters such as antenna type and size, antenna patterns and polarization, gain, gain pattern, Effective (or Equivalent) Radiated Power (ERP), receive and transmit diversity, and proper installation to provide adequate coverage, mitigate interference, and reuse frequency.
- Optimize coverage of a radio system using propagation analysis tools, and appropriate coverage calculation and verification techniques.
- Determine appropriate antenna spacing using adaptive antenna methods and techniques.
- Develop a block diagram of a radio system showing the location of all RF units in the system.
- Perform and interpret RF system measurements, and utilize site survey techniques, using test equipment such as network analyzers, spectrum analyzers, and time domain reflectometers (TDR). Example tests and evaluations include but are not limited to the following:
    - ERP
    - Received Signal Strength Indication (RSSI)
    - Noise Figure/Factor (NF)
    - Noise temperature
    - Receiver sensitivity
    - Sources and impact of external noise
    - Signal-to-noise ratio (S/N)
    - Co-channel and adjacent channel interference analysis
    - Intermodulation interference
- Use computer tools to evaluate radio links and perform propagation studies.
- Rack equipment and properly install waveguide/cabling according to best practices.

- Maintain and repair equipment according to system manufacturer, FCC and Caltrans guidelines.
- Evaluate the pros and cons of common alternatives.

8.2.4 Course Outline and Schedule

Course Modules

1. Microwave Parameters and System Architecture
2. Modulation, Bandwidth, and Capacity
3. Microwave Antennas
4. Radio Wave Propagation
5. Microwave Path Design
6. Telecom Site Preparation
7. Interference
8. Microwave Radio Data Transport
9. Microwave Radio Performance and Alarm Monitoring
10. Protection and Diversity

The course agenda can be found in Appendix C: Radio Frequency (RF) Fundamentals Training Agenda – October 2022.

8.2.5 Equipment and Materials

Students should have the following:

- Laptop computer (Windows or Mac that can run Windows Programs) with Portal software installed
  - Portal software: https://view.highspot.com/viewer/6310998eff3f004bec7a8257
- Aviat Cloud account – https://aviatcloud.com/Splash/Index.aspx; use your work email address and not a Gmail or Hotmail type of address; set up the account at least three days prior to the start of the class.
- Course notebook
- Lab workbook

Aviat Networks to provide:

Radio

- One equipment rack container with -48VDC power supply
- 2 Eclipse Radio Links:
- Link 1: Hot Standby IRU600 with INU, RAC70, DACGE3, and DAC16X
- Link 2: Non-Protect ODU600 with INU, RAC70, DACGE3, and DAC16X
- Both radio links will be connected back-to-back with cables and fixed attenuators to simulate a path and antennas.
- Wi-Fi hotspot for student connectivity to the radios
- 2 Ethernet Testers

- N-Type male connectors (minimum 1 per student), RG8 type 50-ohm coax cable, connector crimper, and other tools for coax cable connector lab.

Customer to provide:

Classroom Set Up

- Training room must be sufficient in size to handle all participants, desks, chairs, and classroom equipment. The room must have AC power and enough outlets to operate equipment and students/instructors' laptops and air conditioning.
- Classroom Equipment - White board, dry erase markers, overhead projector, and screen.
- Desk and Chairs - Desks or workstations with enough room for each student to write, have open books, and laptops.
- Internet Access - Internet access through the server or through client PC.

8.3 Logistics and Course Delivery

Radio Frequency (RF) Fundamentals Training was held October 24-28, 2022, with five full days of training. The Sacramento Regional Transportation Management Center in Rancho Cordova, California, provided an appropriate location for the course. The training room was comfortable and of adequate size for the audience and the course activities. It was also near lodging and dining options for those traveling from out of town.

The course was taught by Jonathan David of Aviat Networks. This contractor was chosen through a formal request for bids.

The student audience consisted of Transportation Electrical Engineers, ITS Engineers, and Electrical Engineers. Students represented five different Caltrans districts. See Table 1 for a list of students. One member of the project team attended to observe, facilitate logistics, and evaluate the course.

Table 1: Radio Frequency (RF) Fundamentals Training course students

Name	District
Lonnie Hobbs	Caltrans District 2
Kenny Shipley	Caltrans District 2
Chaylen Scrivner	Caltrans District 2
Dong D. Lin	Caltrans District 3
Matthew Lella	Caltrans District 3
Berhanu Zergaw	Caltrans District 3
Steven Gee	Caltrans District 5
Eric Carver	Caltrans District 5
Steven Che	Caltrans District 6
Kenneth Wong-Porter	Caltrans District 6
Terry Tran	Caltrans District 9
Kazi Hassan	Caltrans District 9

8.4 Evaluation Strategies

To evaluate the course, the research team developed an evaluation form to be completed by the student participants at the conclusion of the training. The instructor also distributed an evaluation form for the overall course. A member of the PTAP attended the course to observe and evaluate the presentation methods and content. The project team, instructor, and an Aviat Networks representative held a final evaluation meeting to review the course as well as the procurement, planning, design, development, delivery, and logistics.

8.4.1 Overall Course Evaluations

Students were asked to rate the instructor on a one-to-five scale, with one being poor and five being excellent, for his knowledge of the subject matter, ability to answer questions, presentation and delivery skills, preparedness, time management, and how well questions and discussion were encouraged and facilitated. Along with an overall rating of the instructor, the students were asked how likely it was that they would attend another course taught by this instructor. Space was provided for free-form comments.

Second, students rated the different characteristics of the course on a one-to-five scale. Students rated the content of the course as well as the subject matter, level of detail, instructional methodology, presentation structure and organization, and overall quality of the course. Relevancy and application to real situations, and whether the course met student needs and expectations were additional course characteristics appraised by the students. Finally, students were asked to assess the hands-on activities in the course. Space was again provided for free-form comments. To further evaluate the content of the course, students were asked whether they agreed that the correct objectives were targeted.

Course materials were evaluated on the same scale for quality, organization, usefulness, practicality, and potential value as future reference materials. In addition, students were asked to indicate how well the course materials corresponded with the course presentation. Students were given space to provide any relevant comments they might have.

To evaluate the logistics of the course, students were asked to indicate level of satisfaction with the location of the course and the facility/classroom. Course length, pace of course, and time of year the course was offered were also assessed by student satisfaction level. Students could provide comments if desired.

Whether the course would be recommended to others and likelihood of attending another course taught by Aviat Networks were two additional questions on the evaluation form that were included to obtain an overall impression of the quality and value of the course. Students were also asked what they could apply to their job after taking the course as well as difficulties they foresaw in applying the course materials to their work.

Because this course was part of the larger curriculum development project, the evaluation form included an area for mentioning other subject areas in which students were interested in receiving training. Finally, the evaluation asked whether this course had met students' needs and expectations for communications training in RF fundamentals.

The complete evaluation form developed by the research team is included in Appendix D: WTI Course and Instructor Evaluation Form.

At the end of the class, the instructor also distributed an overall course and instructor evaluation form. As this course is part of a larger research project, students completed this form in addition to the form discussed above.

On a scale of one (Very Dissatisfied) to ten (Very Satisfied), students rated the level of technical detail in the course, the usefulness of "hands-on" training, and the amount of time spent on "hands-on" training. They rated the instructor's organization of materials, knowledge of product and course content, helpfulness and willingness to answer questions, and how clear and understandable he presented the materials. On the same scale, students rated the overall satisfaction with the training. Space was provided for free-form responses to what students liked most about the class. The evaluation questionnaire also asked if there were additional services, improvements, or courses that students would like Aviat Networks to provide.

The evaluation form administered by the instructor is included in Appendix E: Aviat Networks Customer Training Course Evaluation Questionnaire.

8.5 Participant Evaluations

The evaluation forms described in the previous section were generally divided into questions about the instructor, the course, course materials, overall impression of the course, and logistics. This section provides a summary of the participant evaluations according to these categories. The full evaluations can be found in Appendix F: Participant Evaluations (WTI) – RF Fundamentals Training and Appendix G: Participant Evaluations (Aviat Networks) – RF Fundamentals Training.

8.5.1 WTI Evaluations

The majority of students rated the instructor "Excellent" or "Very Good" in every category (Table 2, Figure 1). Students felt he was extremely knowledgeable and experienced in the subject matter which are key requirements for the courses delivered through this project. "He was an excellent instructor who had a deep knowledge of the subject." They followed this up with a high rating (4.8 out of 5) on ability to answer questions. According to most students, the instructor answered questions completely and thoughtfully, and he positively encouraged them to ask questions and discuss content. He organized the materials and managed class time appropriately to keep students engaged, actively learning, and on task to cover all the course content as expected. All students rated the instructor overall either "Excellent" or "Very Good" (average 4.7 out of 5) and strongly indicated that they would likely attend another course taught by this instructor (Table 3, Figure 2). A student commented, "Well done to Jonathan for leading this course. Instructors at his experience add tremendous practical and fundamental knowledge needed to have successful training." The student continued, "A+ rating. Thanks, Jonathan, for the great class!"

Table 2: Number of students who rated the instructor at each level.

Instructor	Excellent 5	Very Good 4	Good 3	Fair 2	Poor 1	Average Rating
Knowledge of subject matter	10	2	0	0	0	**4.8**
Presentation skills and delivery	7	5	0	0	0	**4.6**
Ability to answer questions	9	3	0	0	0	**4.8**
How well prepared was the instructor?	5	5	2	0	0	**4.3**
How well did the instructor encourage questions and facilitate discussion?	7	5	0	0	0	**4.6**
How well did the instructor organize and manage the course to stay on task?	6	5	1	0	0	**4.4**
Overall rating of instructor	8	3	0	0	0	**4.7**

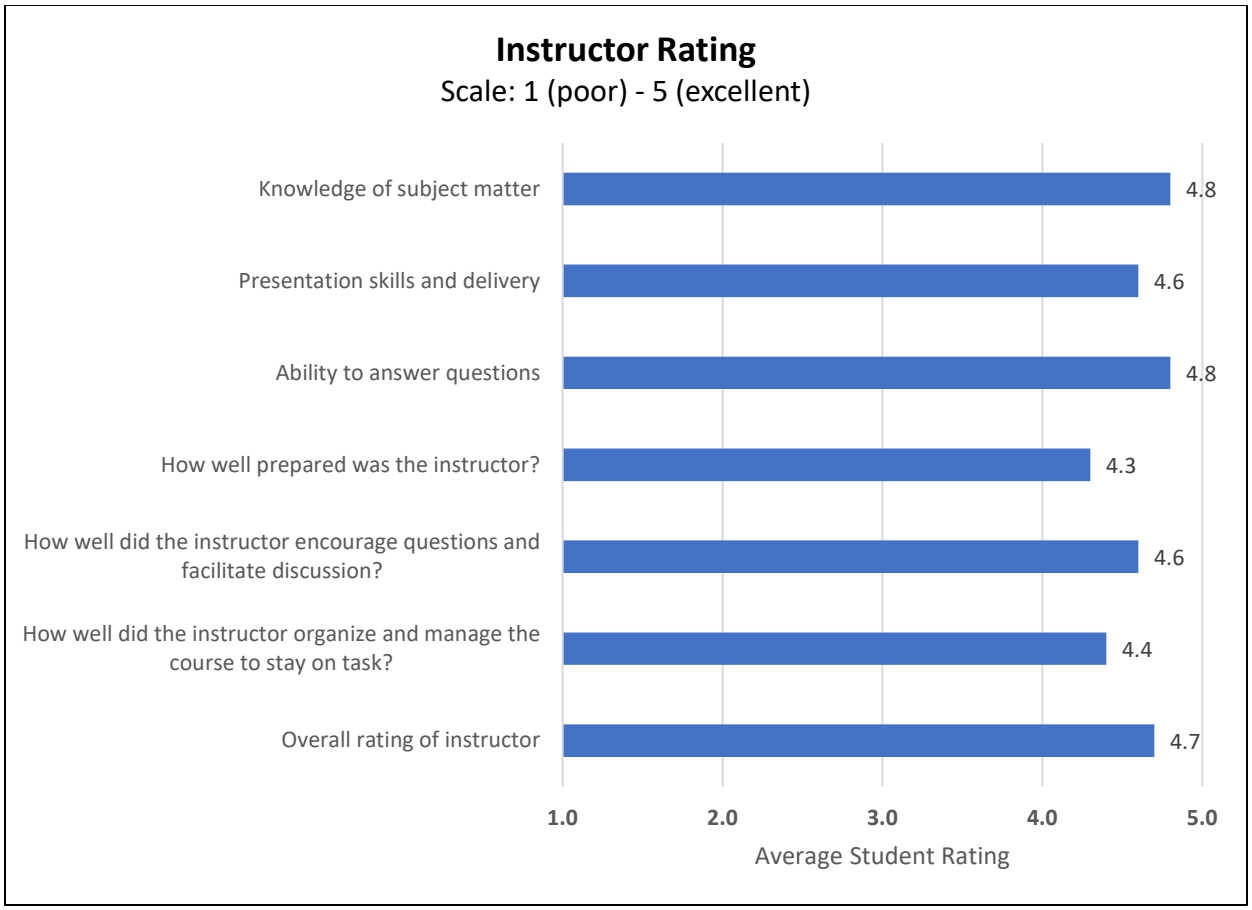

Figure 1: Average instructor ratings.

Table 3: Number of students who would likely attend another course taught by this instructor.

	Very Likely 5	4	Neutral 3	2	Not At All Likely 1	Average Rating
How likely to attend another course by this instructor	8	2	2	0	0	**4.5**

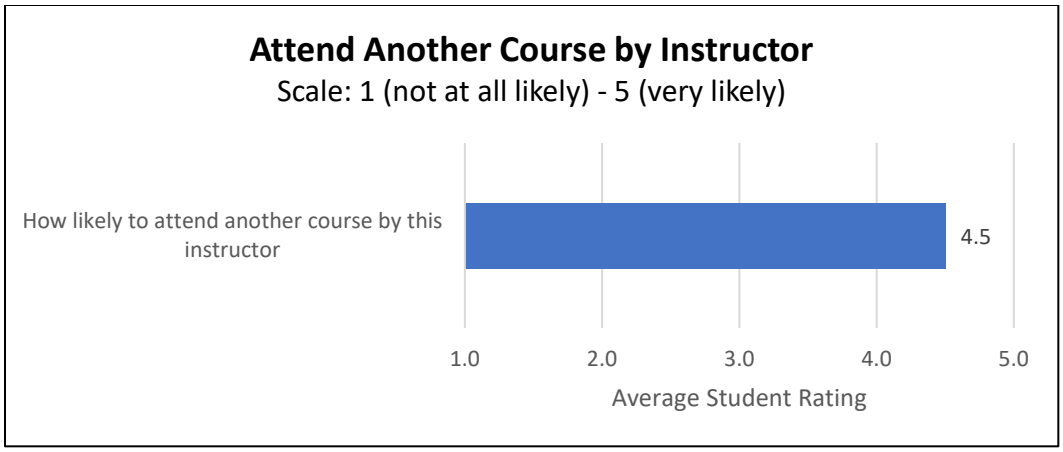

Figure 2: How likely students would attend another course taught by this instructor.

On average, students rated the course organization and structure and how it was delivered between "Very Good" and "Excellent" (Table 4, Figure 3). Students also rated the subject matter and level of detail between "Very Good" and "Excellent." They seemed generally satisfied with the overall content of the course, how easy it was to understand, and how well course objectives were achieved. A less experienced student appreciated the training opportunity: "Fundamentals of RF for someone like me that has little experience in that subject was made much easier to understand from this course." Most students indicated that the course content could be applied to real situations fairly well and indicated that the course was relevant to their jobs. One student said, "Each topic was informational and applicable through real world examples." Another said, "Real world examples helped [me] understand each topic along with the concepts." And another said, "…I really enjoyed the course and subject material. I will use the info from the practical applications the most." However, a different student commented that the course "Covered areas not of interest. Got most of what I needed in about 2 days." Two-thirds of the students did say the course met their needs and expectations "Very Good" or "Excellent." A student commented in this regard: "Yes, this training touched on and explained applicable real-world experiences with background on how to approach deployment / maintenance and troubleshooting." Most students agreed that the correct objectives were targeted and would likely recommend the class to others (Table 5, Figure 4). Overall, the course ratings all averaged 4.1 or higher out of five (5), except for hands-on activities which averaged 3.9.

Table 4: Number of students rating the course and content at each level.

Course	Excellent 5	Very Good 4	Good 3	Fair 2	Poor 1	Average Rating
Content overall	7	5	0	0	0	**4.6**
Subject matter	6	5	1	0	0	**4.4**
Level of detail	7	2	2	0	0	**4.5**
Instructional methodology	6	4	2	0	0	**4.3**
How easy was the course to understand?	4	7	1	0	0	**4.3**
How relevant was the course to your job?	3	7	2	0	0	**4.1**
Hands-on activities	5	3	2	2	0	**3.9**
Application to real situations	5	5	2	0	0	**4.3**
Presentation structure and organization	5	5	2	0	0	**4.3**
How well were course objectives achieved?	6	4	2	0	0	**4.3**
How well did the course meet your expectations?	5	3	4	0	0	**4.1**
How well did the course meet your needs?	5	3	4	0	0	**4.1**
Overall quality of course	6	5	1	0	0	**4.4**

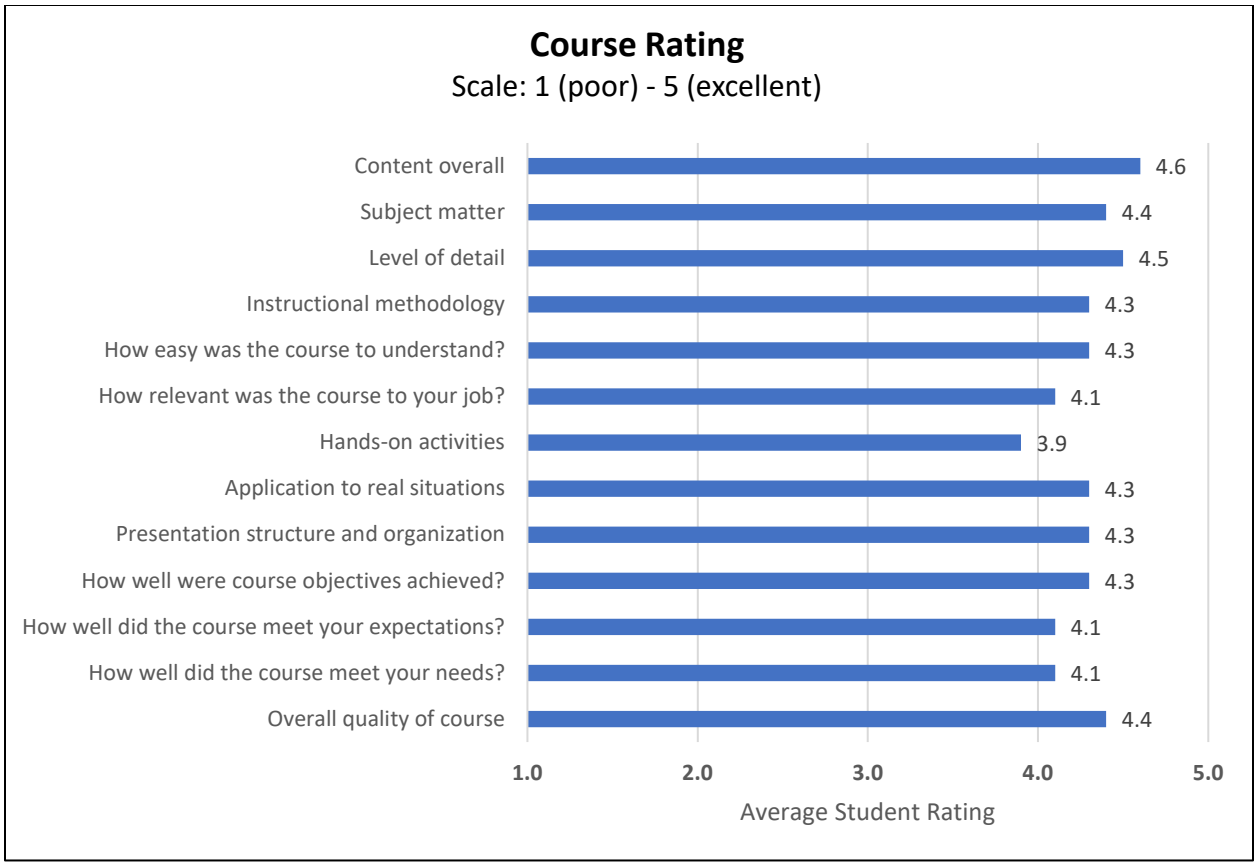

Figure 3: Average course ratings.

Table 5: Number of students indicating agreement that correct objectives were targeted.

	Strongly Agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Average Rating
Agreement on target objectives	6	3	2	1	0	**4.2**

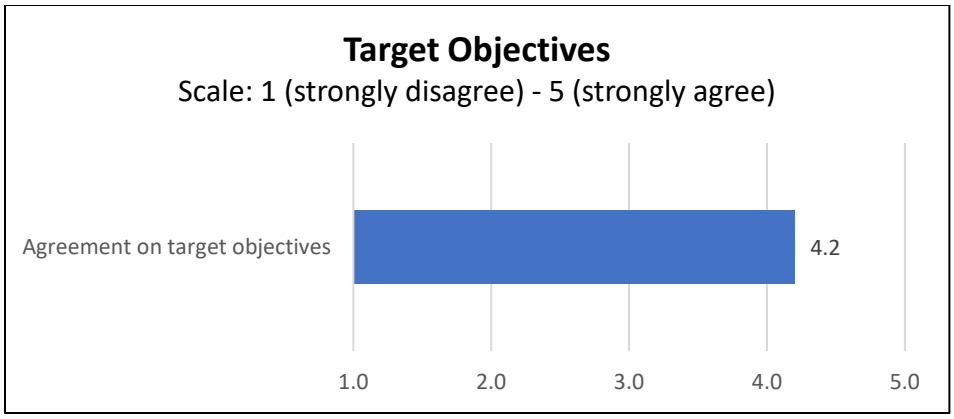

Figure 4: Level of agreement that the correct objectives were targeted.

Hands-on activities have been strongly emphasized throughout all phases of this project to deliver practical and immediately useful training. Two-thirds of the students rated the hands-on activities in this course "Excellent" or "Very Good", while the other third rated them "Good" or "Fair." The instructor noted that only two students completed the lab exercise with connectors. They did the lab one at a time and with varying level of experience among students in the course, students possibly felt uncomfortable with completing tasks in front of the group. A student indicated "the course was well laid out" but also noted that "Sometimes not everyone was able to do the labs." In a comment on the course materials, one student did say that the "Labs [were] hard to follow." One student suggested that the hands-on activities be expanded with "different types of radios and scenarios / hands-on troubleshooting to better understand real world expectations."

The class materials received positive ratings, with most ratings at "Excellent" or "Very Good." Students indicated they were of overall very good quality, easy to understand, well organized, and flowed in a logical fashion. They also followed the course presentation closely which enhances student learning. "I will be keeping all material and notes for future reference and will be sure to share with my colleagues…" There were some rankings at the "Fair" and "Poor" level. As noted above, one student indicated that the labs were difficult to follow, while another student noted that the "font size of the screenshots could be bigger." Refer to Table 6 and Figure 5.

Table 6: Number of students rating the materials at each level.

Materials	Excellent 5	Very Good 4	Good 3	Fair 2	Poor 1	Average Rating
Overall quality	5	4	3	0	0	**4.2**
Organization, flow, and structure of information	6	4	1	1	0	**4.3**
How well did the course materials follow the course presentation?	8	2	1	1	0	**4.4**
Usefulness, practicality of course materials	6	4	1	1	0	**4.3**
How easy were the materials to understand?	4	5	1	1	1	**3.8**
Potential value as future reference material	4	5	2	1	0	**4.0**

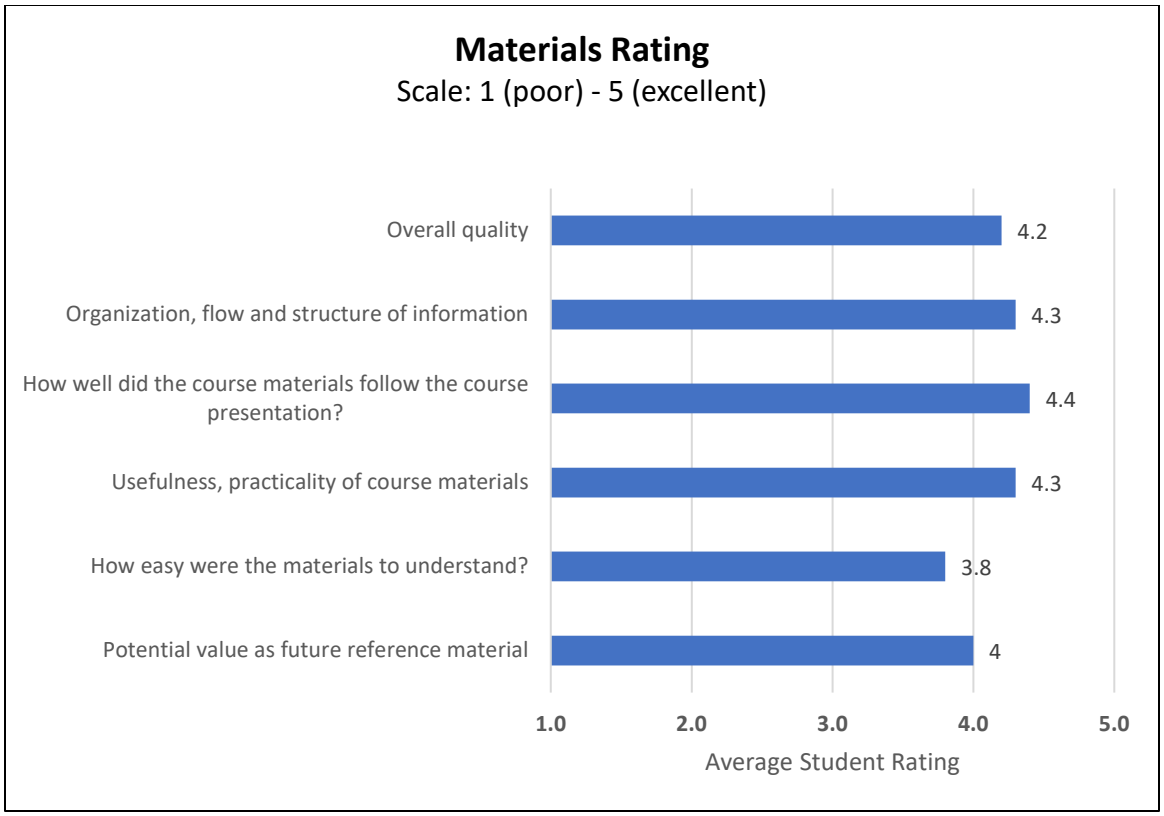

Figure 5: Average ratings for the course materials.

When asked what parts of the training could be applied to their jobs, students listed many of the skills stated in the course objectives. RF communication system and site design and point to point communications, basic understanding of modulation, switching, and routing, and the fundamentals necessary for setting up and installing RF links were mentioned. Specific skills that students learned and could apply to their jobs included determining path loss, SNMP, optimal dish alignment, bandwidth and distance determinations for existing sites, and troubleshooting RF links, including connectivity and configuration. The course was timely in that students could immediately apply what they learned and also felt they would be able to use their skills in the future. "…, but for sure in the future when integrating some elements with RF. Mostly rural sites and maybe the FDWS."

On the other hand, a couple students indicated they may have difficulty applying "some of the management options that were shown," specifically data management and general data configuration. Students also said that applying Aviat specific software and hardware could be challenging given different radio types used across the districts.

Most students were "Very Satisfied" or "Satisfied" regarding the various aspects of course logistics, including location, classroom, course length and pace, and when the course was offered. "All good aspects, no complaints whatsoever." One student did comment, "Course moved very fast and could have been extended for understanding purposes." But another student commented, "… If only need RF knowledge the course could have been much shorter." See Table 7 and Figure 6.

Table 7: Number of students rating level of satisfaction for different aspects of the course.

Aspect	Very Satisfied 5	Satisfied 4	Neutral 3	Dissatisfied 2	Very Dissatisfied 1	Average Rating
Location	8	4	0	0	0	**4.7**
Facility/Classroom	9	3	0	0	0	**4.8**
Course length	7	4	0	1	0	**4.4**
Pace of course	6	4	1	1	0	**4.3**
Time of year course was offered	6	5	1	0	0	**4.4**

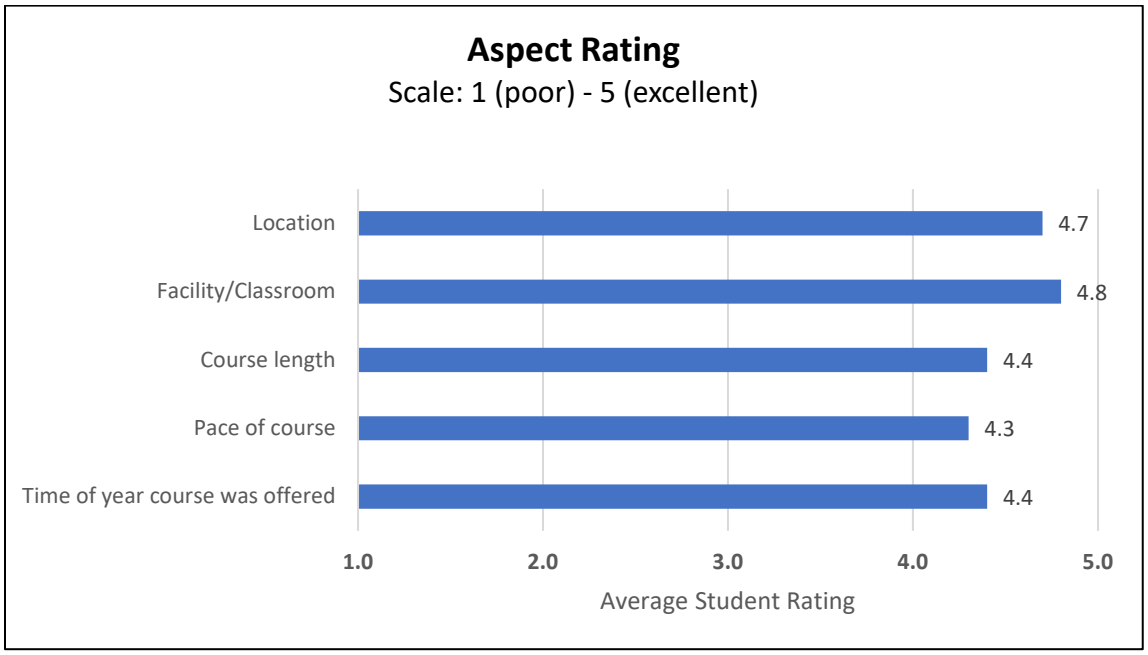

Figure 6: Level of satisfaction with different aspects of course logistics.

All students said they would "Definitely" or "Likely" recommend this course to others (Table 8, Figure 7). One commented that in his district "…there are some more RF applications that others might benefit from." Another student said, "The core concept was one worth knowing." And another student commented, "I learned a lot of material that is not covered in other courses." Most students also confirmed that the course met their needs and expectations for RF training, citing skills and applications of use. "Yes. The RF microwave knowledge can be applied to different projects that might require [evolution] of different technologies."

Table 8: Number of students likely to recommend course to others.

	Definitely 5	Likely 4	Neutral 3	Maybe 2	No 1	Average Rating
Recommend to others	7	5	0	0	0	**4.6**

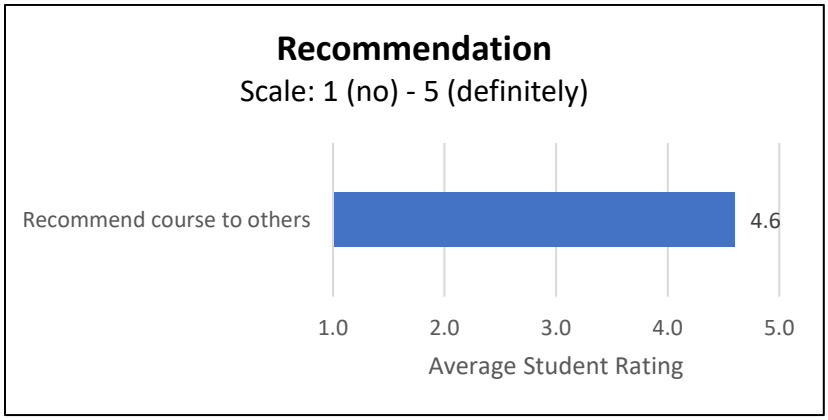

Figure 7: How likely students were to recommend this course to others.

This training topic was chosen based on results of the needs assessments conducted in this project phase and previously. (Refer to *Section 7 Needs Assessment and Gap Analysis* for details on the recent needs assessment.) Student ratings and comments indicate the course was valuable for building professional capacity relative to ITS communications and most students said they are "Very Likely" or "Likely" to participate in another training course as part of the Professional Capacity Building for Communications project (Table 9, Figure 8).

Table 9: Number of students likely to participate in another PCB training.

	Very Likely 5	4	Neutral 3	2	Not At All Likely 1	Average Rating
Participate in another training for PCB	8	3	1	0	0	4.6

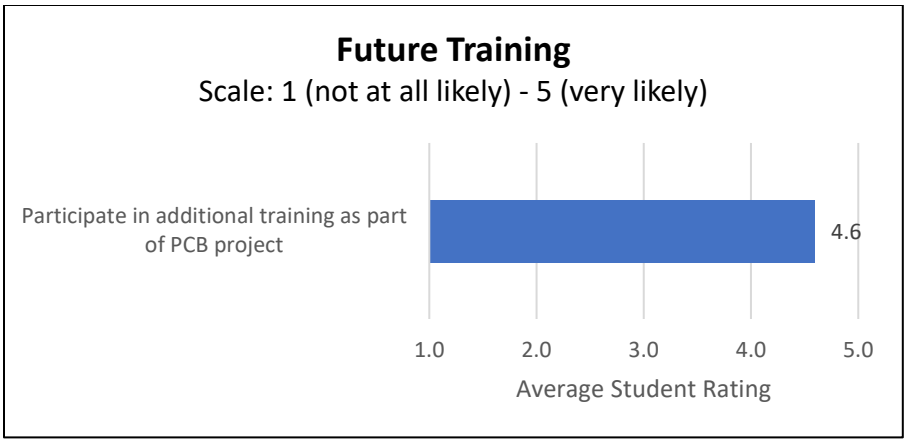

Figure 8: Average rating for how likely students would participate in another PCB training.

Students are interested in training on the following ITS communications topics:

- Fiber optic[s]
- Cellular communication
- Networking / switching
- Video encoding and streaming
- Network QoS
- Automation / coding
- Basic practices for equipment installs
- POTS communication
- Fiber communications
- Networking, routing, switching for CT use
- Statewide ATMS
- Newer smart systems for self-driving cars and the like
- TCP/IP
- Solar

The average ratings for the evaluation categories are summarized in Table 10 and Figure 9. The full evaluations are in Appendix F: Participant Evaluations (WTI) – RF Fundamentals Training.

Table 10: Average ratings for the evaluation questions/categories.

	Average Rating
Average Instructor Rating	**4.6**
Attend another course by this instructor	**4.5**
Average Course Rating	**4.3**
Agreement on target objectives	**4.2**
Average Aspect Rating	**4.5**
Recommend to others	**4.6**
Average Materials Rating	**4.2**
Participate in additional training through PCB project	**4.6**

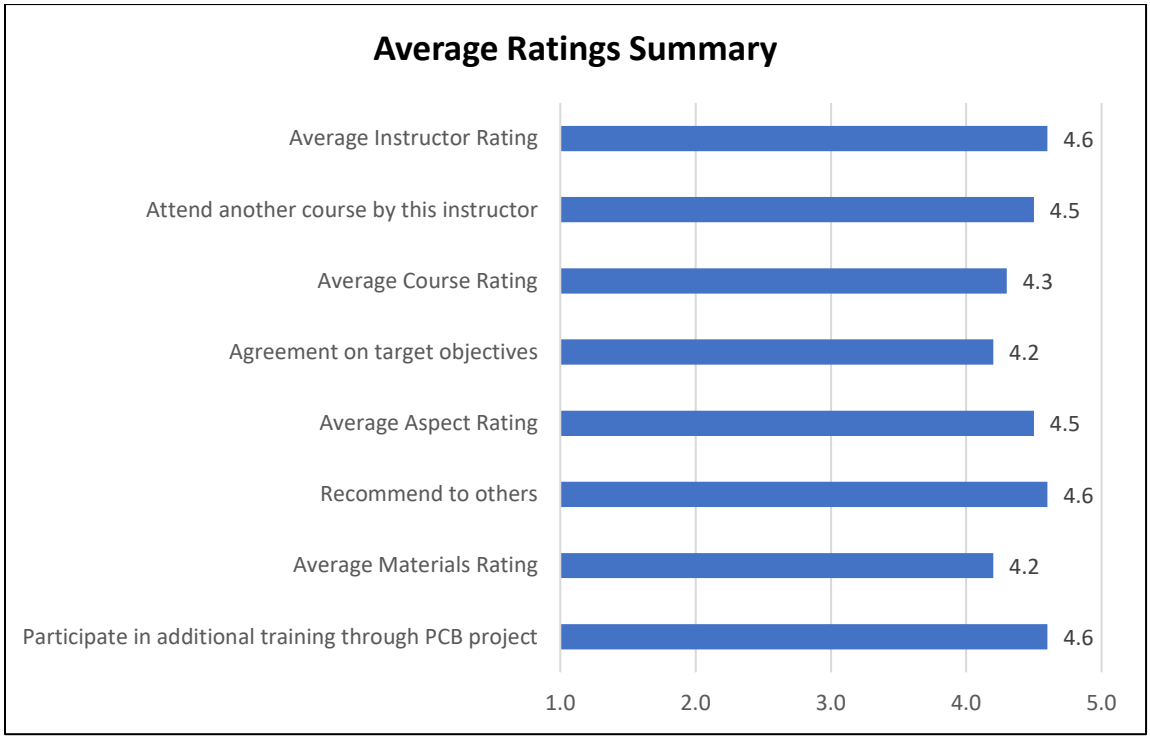

Figure 9: Average student ratings summary.

8.5.2 Aviat Networks Evaluations

Questions, ratings, and comments were similar to the evaluations described above. Students indicated the instructor was highly knowledgeable, helpful and willing to answer questions, and presented the material in a clear and understandable manner. Students were also highly satisfied with how the instructor organized the course materials. In comments about what they liked most about the course, students

noted the instructor's knowledge and experience saying, "I appreciated the real-world applications and experience provided by the instructor. It placed an emphasis on what/why we're approaching things in specific ways as well as what we might see in the field." And "The instructor's knowledge of the practical applications, historical and technical backgrounds, and presentation of the fundamentals were very insightful and useful." (Table 11, Figure 10)

The average rating for level of technical detail was 9.25 out of 10 indicating that students felt this course met expectations for an in-depth training. The amount of hands-on training and the usefulness of such training were rated around eight (8) out of ten (10), which still indicates a high level of satisfaction, but just a bit less than the other parameters rated. One student said, "For improvement the labs were hard to understand and follow." Another student indicated that lab equipment was limited which made it challenging to complete the labs. See Table 11 and Figure 10 for details.

Students were highly satisfied with the training overall with a 9.5 average rating (Table 11). In addition to the instructor's knowledge and experience, students liked the history of microwave radios and the software discussed. "Very informative" one student said.

To improve the course, one student commented that the pace was very quick, and it would be helpful to spend a bit more time on some topics. Another student gave specific suggestions for practical skills that they thought more time should be spent on learning: "More attention to designing a system and calculating a link, troubleshooting transmission lines and power levels. Having a software version of the hardware (similar to Cisco) that would allow each student to create links and test on their own machines would be helpful."

Table 11: Number of students who rated the training and instructor at each level (Aviat Networks evaluation).

Question	1	2	3	4	5	6	7	8	9	10	Average Rating
Level of technical detail	0	0	0	0	0	0	1	1	1	5	**9.3**
Usefulness of "hands-on" training	0	0	0	0	1	1	0	2	2	2	**8.1**
Amount of time spent on "hands-on" training	0	0	0	0	1	1	2	1	1	2	**7.8**
Instructor's organization of materials	0	0	0	0	0	0	2	0	2	4	**9.0**
Instructor's knowledge of product, course content	0	0	0	0	0	0	0	1	0	7	**9.8**
Instructor's helpfulness, willingness to answer questions	0	0	0	0	0	0	0	0	1	7	**9.9**
Instructor presented material in a clear and understandable manner	0	0	0	0	0	0	0	0	3	5	**9.6**
Overall satisfaction for the training	0	0	0	0	0	0	0	1	2	5	**9.5**

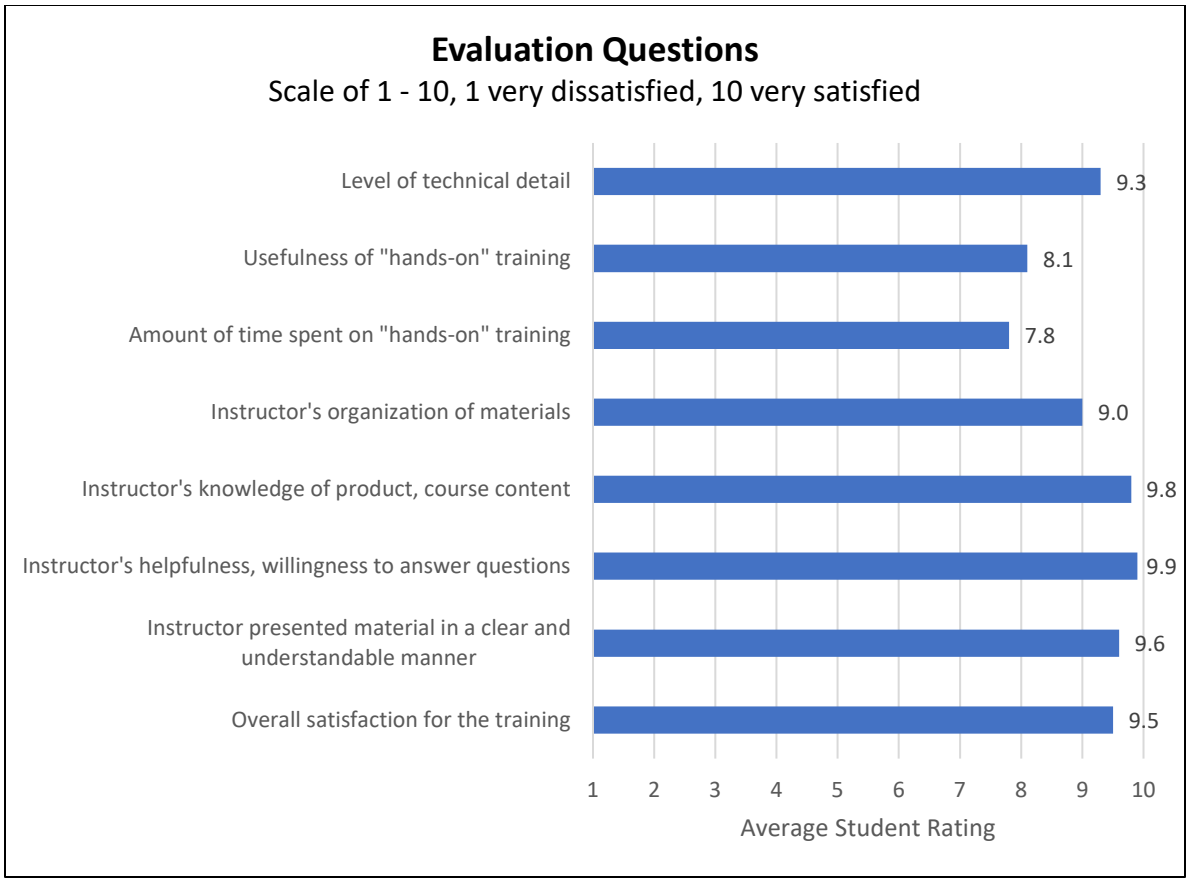

Figure 10: Average course and instructor ratings (Aviat Networks evaluation).

Complete evaluations and comments are in Appendix G: Participant Evaluations (Aviat Networks) – RF Fundamentals Training.

8.6 Project Technical Advisory Panel (PTAP) Evaluation

While participant evaluations were important and provided beneficial feedback, it was very valuable to have a member of the PTAP attend the class in a review capacity.

Overall, the PTAP felt the course was very well-received and the entire process of procurement to course delivery went smoothly. Aviat Networks personnel commented that the process and delivery was very well organized which speaks to the robust nature of the limited solicitation RFB and the course development process that has been established through this project.

- PTAP members said the course was overall positive and definitely a good use of time. Comments made beyond evaluations to the PTAP and the instructor supported the overall positive reception, “Great class!”
- The group was pleased with the amount and level of interaction and discussion. Students were engaged throughout the course.
- A large amount of content was presented on an aggressive timeline. This “firehose” effect has been the preferred method of presentation for these courses – presenting a wealth of information possibly beyond what the students could master in the allotted time, but then be able to go back

to the comprehensive materials for specifics. Indeed, the courses are designed such that students would be challenged, learn the foundational skills to solve a problem, and leave with the desire, resources, and ability to go back and learn more about topics relevant to their particular challenges.

- The PTAP indicated that more time could have been spent on developing a link budget and using link software, but the course still "covered a lot of ground."
- Like the student evaluations, the PTAP noted that the hands-on activities could be enhanced. The number and type of tools and workstations appeared to be limiting and some activities had to be done one at a time / individually. For example, only two students completed the connector lab. Given varying levels of experience, students may have been uncomfortable attempting the work in front of the group.
- The course materials were spiral bound and good quality. They were readable and matched the course presentation. They will also be useful as a future resource. PTAP members and students appreciated having a hard copy of the course materials.
- Equipment for the training course was delivered on time as were the course materials. Room set-up went smoothly. The training began on time and stayed on schedule throughout the week.
- The PTAP was satisfied with the curriculum and the materials. Unlike the previous RF System Design course, this training did meet the project's expectations and requirements. It is usable in the future and ready to be delivered again with minimal revision.
- The time of year the course was delivered was appropriate given work schedules and seasons.
- The facility and training room were adequate for the course. Size, lighting, access, and projection equipment were comfortable and appropriate.

8.7 Recommendations

Based on the planning, execution, results, and evaluation of this course, the research team makes the following recommendations:

- The time of year the course was held seemed appropriate and is likely the best choice. Consistently holding training at this time of year is beneficial. The late October time frame is generally after summer projects and not quite into full winter maintenance work. A summer course may also be a feasible choice, possibly in conjunction with the Western States Rural Transportation Technology Implementers Forum (http://www.westernstatesforum.org/), which is a technical meeting attended by many in the target audience. March and April are other options.
- The full week length of the course was appropriate and necessary to address the topic and content in sufficient detail and with practical, hands-on applications. Consideration should be given to shifting the start time on the first day of the course to a little later in the morning to accommodate those traveling from longer distances.
- The requirement for a minimum of 25 percent of class time devoted to hands-on activities helped ensure that the course was practical and applicable and not limited to lecture and slide presentations.
- It is critical to maintain the high standards set forth in this project regarding the content and delivery of these courses – that high quality technical content be delivered in a challenging environment by an expert in the field. The curriculum and presentation should not be "dumbed

down" but instead students should be "brought up" to a higher level of expertise. Students should come out of a course challenged but with a solid understanding of the material and the different options available for solving a communications problem. Furthermore, the instructor must have practical, hands-on experience in the field for a length of time necessary to be considered an expert, in addition to being a quality instructor.

- Given comments about type and availability of tools and equipment to do the lab exercises, the PTAP might consider clarifying needs/expectations in advance and working with the instructor to ensure that sufficient equipment/tools are available.
- Course materials (i.e., student materials) should be provided in printed form, in color and appropriately bound. Alternatively, course materials could be provided in an electronic format that allows printing and is easily accessible in the future.
- The contractor was selected through a formal limited solicitation process. This process allowed the project team to set clear expectations and standards for the instructor, content, materials, delivery, and logistics, and have the leverage to hold the contractor accountable through the duration of the contracted services agreement (CSA). It is highly recommended that a similar process and Request for Bids be used for future training opportunities.
- The Scope of Work for the CSA should include a timeline and deadlines for various steps in course development and delivery (i.e., due dates for draft materials, final materials, equipment list, evaluations, etc.) This establishes accountability, but also provides the opportunity to review, evaluate, and approve content, materials, presentation, and activities to ensure the course and its delivery will meet the needs of the students and expectations for the project.
- The one hour "preview" presentation, which included a description of a hands-on activity, was helpful to confirm the pedagogy of the upcoming course.
- As mentioned above, this instructor's level of knowledge, experience, and ability to deliver were keys to the success of this course. It is recommended that potential course instructors be thoroughly vetted by the PTAP/project team/selection committee to determine levels of knowledge and experience.
- It is further recommended that instructors be included in course curriculum development from the beginning and throughout the preparation. Clear expectations for relevancy and laboratory exercises must be expressed and understood by all involved in the development process. Solid confirmation of actual hands-on activities to be conducted during the course should be received from the instructor by the PTAP and research team.
- It is recommended that direct means for communication with the instructor throughout the process be provided to the project team. (We note this because the project team was not given direct access to an instructor in the course offered in Phase 1, and there were resulting challenges.)
- It is further recommended that the PTAP contemplate the opportunity to facilitate student certification if the topic and training are appropriate.
- Class size should be about 10 to 12 students to ensure student engagement and quality of student and teacher interactions. An effective means of utilizing a waiting list should be implemented.
- When choosing PCB training offerings, the PTAP might consider additional training presentations. For example, short courses (one or two days) on a specific topic to follow the primary training - solution specific and minimum of theory.

- It is further recommended that the PTAP explore the possibility of engaging Caltrans engineers to develop and present professional capacity building courses in ITS communications. We note that this would likely require a sabbatical program for Caltrans engineers.
- Having a project team / PTAP member attend the course was valuable and should be continued in some capacity for future training classes.
- Regarding logistics, course materials and equipment should be shipped directly to the training location. It is preferable to have the course materials and equipment set up at least one business day prior to the start of the course. Projectors and network connectivity should also be tested in advance and backup arrangements made if needed.

9 Next Steps

This project is a productive step towards providing critical professional capacity building by way of advanced, technical training to Caltrans ITS engineers and technicians. Another training was developed, procured, and successfully delivered during project Phase 5. Caltrans validated the solicitation process and the quality of the courses delivered through this project by procuring several classes separately. The comprehensive curriculum was revised and the list of identified training providers updated. A needs assessment and gap analysis were also completed.

Based on the experience gained in completing this phase of the project and with input from the PTAP, the research team suggests the following next steps:

- ITS communications engineering is a mission critical skill – for rural areas as well as more urban districts. As technologies continue to evolve and new technologies become available, ITS engineers and technicians must understand the underlying engineering principles and the reality of what is possible in order to design a robust and reliable communications network. The curriculum developed through this project and the trainings delivered to date have aimed to develop the systems engineering approach to communications, building skills for analyzing sites and identifying the best solutions for the application at hand. The needs assessment and gap analysis completed during this project phase clearly showed a need for continued capacity building in ITS communications that is detailed and beyond glossy specification sheets from vendors.
- Transportation agencies are faced with the challenge of finding and retaining qualified staff with practical, real-world skills. To address this workforce challenge, coupled with the critical skills required for ITS communications engineering, it is crucial to continue to provide relevant, practical professional capacity building opportunities like the courses developed and delivered through this project.
- At the same time, the subjects and topics addressed in the Curriculum Scope and Sequence are complex and require study and experience over many years. The PCB courses are meant to provide basic training and familiarization of the identified technologies; significant study and effort over time is necessary for mastery of these complex subjects. It is important for Caltrans to consider building the professional capacity of staff members over time, not just with one-time classes.
- The curriculum should be updated to reflect the changing state of the practice in ITS communications. One aspect that may merit consideration is further specification of the target audience (i.e., repair/maintenance, system implementation, systems design, system administration, operations, etc.). The expectation is to provide relevant, high quality technical content in a challenging environment.
- Six training courses have been developed and delivered through five project phases. Competent instructors and subject matter experts have already been identified and content is well established. Caltrans has used that course content and those instructors to procure additional training for ITS engineers. How best to utilize what has already been done and not “reinvent the wheel” is still an important consideration for continued professional capacity building for communications.

- Delivering hands-on and practical, relevant training has been at the core of this project. While alternative delivery mechanisms have been considered, the experiences of the PTAP and delivery of the courses indicate that onsite delivery by industry recognized experts is the most effective and preferable to such methods as web-based, independent study, or condensed versions. However, the project team concedes that the IP Fundamentals courses can still be effectively delivered in a virtual environment and should be pursued.
- Carefully evaluate how to approach securing subject matter experts who can deliver quality training that is hands-on and applicable to transportation in general and to rural ITS engineering specifically. Although outside the scope of project work, further consideration should be given to sabbatical programs for the development of curricula by expert Caltrans personnel. This may be a feasible option for developing one- or two-day trainings on a specific topic (e.g., Plant Wired core / plant wiring basics – 2 days, structured cabling for TMCs – 3 days, Plant Wireless Core – 1 day, Network Security – 3 days, Telco Wired core plus another Telco Wired topic – 1 to 2 days, Vendor Specific Equipment training – 2 days, etc.)
- Because the curriculum has been established and multiple successful courses already delivered with experienced instructors, further training development and delivery could be approached in several ways: a) repeat a previously offered course in full or go into more depth on a particular topic(s) from a previous course; b) offer intermediate or advanced training in topics already addressed (i.e., RF Engineering, IP fundamentals, Telecom Wireless); c) adjust training already delivered to more specific audiences (e.g., the optical fiber course was delivered to ITS engineers and technicians and then was adapted for delivery to maintenance electricians); and/or d) develop a course in a new subject or topic. This decision should be guided by the needs of Caltrans engineers.
- While not pursued within the scope of this project, the possibility of offering professional development credits or more direct preparation for certification exams are concepts to bear in mind for future professional capacity building. Coordination with college/university programs or other technical training programs is another option to investigate to ensure quality professional training programs.
- This project has been developed based on the needs of Caltrans ITS engineers and technicians. The project team is unaware of any similar efforts at other state departments of transportation (DOT) although interest in the project has been expressed by other DOTs through the Western States Rural Transportation Consortium (http://www.westernstates.org/). The potential exists for adaptation, adoption, and delivery of ITS communications professional capacity building curricula in other states and on a national level. While some informal discussions with FHWA personnel have occurred in the past, future research should investigate opportunities to sustain the program as well as probe prospective “sponsor” organizations (e.g., FHWA, IEEE, ITSA).

10 Project Summary / Impact

To develop the rural ITS workforce and maximize the benefits of a more efficient and better quality rural transportation information and communications system, the goals of this project were to develop a comprehensive curriculum and conduct relevant training. This project has successfully met these goals and established deliverables that will continue to have an impact into the future.

- Six different training courses have been developed and delivered. These courses have all been full weeklong trainings (40 hours) with a minimum of 25 percent of hands-on laboratory work/exercises and taught by a subject matter expert with real-world experience in the training content.
- Three needs assessments and gap analyses were conducted to develop the curriculum and maintain its relevancy. In addition, these assessments directed decisions on which courses to develop and procure initially as well as those that should be delivered again.
- This project established quality syllabi and identified experienced instructors. This streamlined the Caltrans processes for training procurement which in turn allowed more staff to be trained. The additional training has helped build the professional capacity of the Caltrans workforce relative to ITS data communications. The courses in Optical Fiber, Telco Wireless Fundamentals, and IP Fundamentals, have been directly procured by Caltrans, with similar content and the same instructors:
    - IP Fundamentals – six additional courses
    - Optical Fiber – six additional courses, two of which were adapted to target maintenance electricians.
    - Telco Wireless Fundamentals – one additional course
- Based on the positive experience and feedback from the IP Fundamentals course(s), Caltrans contracted with the same vendor to develop and deliver an Advanced IP Networks / Protocols training. Four of these courses have been delivered.
- Close to 70 students have been trained through the six original courses developed and delivered through this project. An additional 244 students completed training through the courses that were repeated. These students came from around the state.
- The breadth of content covered in these training courses is extensive. At the same time, it is practical, timely, and relevant to Caltrans transportation systems.

The immediate and future impact of this project is evident in student comments and testimonials. The following are testimonials from students after taking some of the original professional capacity building courses.

Phil Graham was an electrical engineer in Caltrans District 9. Headquartered in Bishop, District 9 is two counties in eastern California along the Nevada border. Arguably one of the more diverse Districts with respect to terrain, District 9 is very rural. Phil was a student in three of the Professional Capacity Building classes. What he learned in the courses allowed District 9 to make use of technology they maybe wouldn't have been able to otherwise as well as make critical improvements to existing systems. Phil said:

> *"The training courses were quite helpful. The RF class helped expand on my knowledge of wireless communication systems, which we use extensively. The*

fiber optic class was both timely and challenging, as my knowledge was quite limited and D9 is about to receive 6 dark fibers from the Digital 395 Project that runs for hundreds of miles through the heart of our District. I'm now able to design the systems that will be required for us to actually use these 'free' fibers.

The classes have helped build my technical knowledge but perhaps just as importantly, they have helped foster working relationships. The other help to me is to see that there are ITS practitioners that pioneer new ways to improve the state of the practice in spite of the obstacles."

- Phil Graham, Transportation Engineer Electrical (retired), Caltrans District 9

Jeremiah Pearce is an ITS engineer and Chief of the Office of ITS Engineering and Support in Caltrans, District 2, in northern California. District 2 has been a leader in ITS deployments and a champion for many of the projects conducted through the Western States Rural Transportation Consortium. Jeremiah has been a student or PTAP observer for most of the PCB for Communications courses and had this to say about his experiences:

"What I like most about the PCB classes is that they are hands on and delivered by industry experts. The learning and experience are invaluable. The fiber optic course was very useful as I was using information and techniques in the field within weeks of taking the class."

- Jeremiah Pearce, Chief, Office of ITS Engineering and Support, Caltrans District 2

Mike Beyer is also an ITS engineer for Caltrans District 2. He was a student in the September 2013 course on IP Networking Fundamentals and Usage as well as the 2015 Telco Wireless Fundamentals course. He says:

"The IP class was timely in that we are interested in testing some advanced telco provided services, like metro ethernet, and having a better idea of how the Telco's handle those service types inside the Central Office makes our decision making process more informed.

The Telecom Wireless Fundamentals course was very timely and packed with solid information regarding the past state of the art, the currently emerging state of the art, and how that will affect our deployment of new cellular systems and the refresh of our existing systems. In addition, there were a plethora of best practice procedures for planning and deploying new systems. If that weren't enough, the open discussions between students of what is working in the field and what isn't, in the presence of a seasoned telecom wireless professional like Scott Baxter, added a depth of understanding to why some methods and specific devices were working and some not; they proved to be very useful discussions."

- Mike Beyer, ITS Engineer, Caltrans District 2

Luis Torres is a Transportation Electrical Engineer in Caltrans District 10 headquartered in Stockton. District 10 is comprised of several counties in central California. Luis and a colleague participated in the

optical fiber course in September 2012. He had this to say about how the course has influenced his work in Caltrans District 10:

> *"I was extremely pleased to learn the design process of the fiber optic systems. Having the calculation sheet provided by the instructor has improved my estimating immensely.*
>
> *I would recommend this course to anyone within the public or private sector.*
>
> *Recently, I assisted with the implementation of the first field elements via fiber optic within District 10.*
>
> *Thank you for your continuous support."*

- Luis M. Torres, Transportation Electrical Engineer, Caltrans District 10

Michael Mullen is a transportation engineer electrical for Caltrans District 3 at the Sacramento Regional Transportation Management Center. Michael and a colleague participated in the optical fiber course in September 2012, the IP Networking Fundamentals and Usage course in 2013, and the 2015 Telco Wireless Fundamentals course. His work in District 3 has been impacted by what he learned in the courses as he describes below:

> *"The PCB Fiber Optic training course, I would strongly recommend to others. It has helped me understand the different terms of the fiber optic world, create effective and accurate cost analysis, how to test installed fibers, and communicate with colleagues about this technology.*
>
> *The IP Networking training course, I would strongly recommend to anyone that wants to learn more about the history, where it is today, and where networking will most likely be in the future. It has helped me understand the different protocols, a proper way to understand subnets, and troubleshoot different potential IP networking problems."*

- Michael Mullen, Transportation Engineer Electrical, Caltrans District 3

Shima Afshari Wollman is a Traffic Engineer Electrical in Caltrans District 6 which has its headquarters in Fresno. She was a student in the IP Networking Fundamentals and Usage course in September of 2013. Right after the class she shared this with the project team:

> *"I'd like to thank you … for the great training you organized. It was one of the best trainings I have had for a long time. The instructor was very knowledgeable. He had a great ability to transfer his knowledge and keep the class interesting and motivated. His class was way far from being a boring networking class. Not only did I learn a great deal about networking, I also enjoyed being in the class. Thank you again and please let me know next time you have a training as well organized as this one."*

- Shima Afshari Wollman

One of the goals of the PCB training courses is to integrate relevant, practical examples and exercises in the course materials. Shima further commented on the IP networking class in this regard:

> *"The IP networking class was beyond my expectation. The instructor created a friendly and comfortable environment. Even though networking is not an easy subject to grasp quickly, he was able to transfer his knowledge in an understandable way by using everyday life examples."*

- Shima Afshari Wollman, Traffic Engineer Electrical, Caltrans District 6

Here are some comments from students about the value of the professional capacity building training courses:

- *"Course provided exactly what our jurisdiction was missing in terms of design to hands on."*
- *"Very valuable training - will use in my job and instructor was excellent."*
- *"The level of detail presented was excellent as was the subject matter."*
- *"This course provides valuable information to engineers mostly working in design. I suggest our inspecting electrical engineers participate to get the maximum effect on our fiber projects."*
- *"The course would be very beneficial to my coworkers and friends."*
- *"We need more classes like this. It directly related to my job and will help me substantially. The objectives were pretty much met."*
- *"The course met my needs for the type of applications used in my district and exceeded in other areas of coverage."*
- *"The course was an extremely good primer for people with little knowledge of RF systems."*
- *"Fundamentals of RF for someone like me that have little experience in that subject was made much easier to understand from this course."*
- *"This class taught me a lot of new topics relating to RF system design, more than I knew before. I would recommend this course to anyone interested in designing RF systems."*
- *"[The course was] very applicable to understanding basic pit falls and 'behind the curtains' of the technologies of wireless."*
- *"The core content was [one] worth knowing."*
- *"I learned a lot of material that is not covered in other courses."*
- *"Very thorough and easy to understand. Would take another course again."*
- *"The instructor covered both the practical and theoretical aspects well."*

This is how students are directly applying what they learned in the training courses to their job:

- *"RF communication design."*
- *"Point to point communications, RF, switching and routing."*
- *"Setting up RF links, understanding modulation, basic routing/switching understanding."*
- *"Determination of path loss and site design for RF links."*
- *"SNMP."*
- *"Basic understanding of radio path and set up for install application."*
- *"RSSI dish alignment."*

- *"…for sure in the future when integrating some elements with RF. Mostly rural sites and maybe the FDWS."*
- *"SNMP Traps and monitoring, troubleshooting radio connectivity and configuration. Bandwidth and distance determinations for existing sites."*
- *"Troubleshooting RF links."*
- *"Cooling system, power requirements, design, sizing of data center, etc."*
- *"Collect and log info such as power consumption for network / servers / video systems. This info should come in handy in future design / remodel."*
- *"Structured cabling - network design and probably I [will] get a chance to use grounding."*
- *"If we have a new data center I will be prepared to give some solid input to the design. Also how to manage a data center."*
- *"Rack layout, cabling, and grounding. Power and mechanical considerations."*
- *"Will be building out small telecom and refreshing main equipment room."*
- *"Yes, we will build TMC in the next five years."*
- *"Knowledge of TMC / Data Center materials / rules for design and development."*
- *"This course helps identify concerns for reliable data infrastructure that can be applied across the board in our ITS infrastructure."*
- *"Planning techniques. Documentation."*
- *"Power per row, cooling recommendations, future capacity planning, evaluating current capacities."*
- *"Data center upgrades for UPS and network room rearrangement."*
- *"Brought up two very immediate solutions to ongoing problems."*
- *"I am in charge of CMSs (Changeable Message Signs), Highway Advisory Radio, and EMSs. To know how to configure routers and how to work with wireless will help me a lot."*
- *"Application of wireless technology, and the tools and process of determining what is best for the application."*
- *"Using signal strength and quality tools when implementing wireless in field locations."*
- *"The understanding of antenna placement and diversity. General LTE/"4G" understanding of wireless encoding/frequency methods."*
- *"Evaluation of LTE sites, deployment of LTE modems - tools presented in this training will help me in deployment of these modems and make informed decisions on type of antenna needed to boost poor signal locations."*
- *"Location of antennas and types. Analysis of RF technology for cellular applications as it relates to different carriers."*
- *"Knowledge of routing protocols and MPLS. Stronger Wireshark skills."*
- *"IP subnet structuring, QoS, routing and overall depth of knowledge."*
- *"IP addressing of various devices during configuration."*
- *"Mostly construction inspection/acceptance."*
- *"Using the OTDR and specifications for the design of fiber networks. Also, I will now be able to talk to the fiber experts with minimal misunderstandings."*
- *"Single mode fiber concepts and fusion splice, system design. Everything I learned is applicable."*
- *"OTDR testing, splicing, some design, troubleshooting."*
- *"Design and testing / inspecting information."*

- *"Fusion splicing, OTDR Testing, insertion testing, and much more."*
- *"Selection of antenna and good understanding of the advantages and disadvantages of each antenna. I will use information learned from this class to troubleshoot sites that have bad or no signals. I may also be using some of the programs presented in class to do/help do point to point connection of several miles apart and also applying concepts of reflection, refraction, and fading learned from class."*
- *"These days it is crucial to know this type of RF information to be able to work with adjacent local agencies and be able to communicate with them. Specifically in the areas of interconnecting signals. (Traffic signals)"*
- *"Wireless communications design and maintenance."*
- *"Adjust modulation type to increase fade margin. MIMO if applicable."*

This project directed the development and evolution of a robust training curriculum that meets the needs of ITS engineers for professional capacity building in ITS communications. Technical, in-depth training courses taught by subject matter expert instructors have been delivered. These courses incorporate hands-on, practical, and relevant materials. The project has identified quality instructors and established content, process, and procedure for procuring additional training. In summary, this project has been extremely successful in workforce development for mission critical skills in ITS communications. Its impact has been immediate and will last into the future.

11 Appendix A: List of Identified Training Providers – Radio Frequency (RF) Fundamentals Training

The following list is dynamic. It includes identified vendors and training providers that appear to have the qualifications listed in the RFB, including on-site course delivery, ability to customize content, hands-on exercises, and an established course(s) that addresses most of the expected learning objectives. The list was compiled through PTAP recommendations, word of mouth, recommendations from instructors, and an extensive web search. The expertise of vendors that submitted a bid was evaluated by the PTAP based on the approved limited solicitation scoring rubric. A provider was further vetted after a contract was signed and prior to course delivery. For simplicity, it should be noted that the following list only includes those who received the most recent RFB. The overall list of identified training providers represents a best effort and there may indeed be other possible providers not listed here. In turn, the procurement process is open and other qualified vendors are eligible to bid.

11.1 Aviat Networks

Aviat Networks, Inc.
200 Parker Drive, Suite C100A
Austin, Texas 78728
(512) 265-3680
www.aviatnetworks.com

Individual Contacts:

- Ali Hirsa: Ali.Hirsa@Aviatnet.com
- Laurant Brigdan: laurant.brigdan@aviatnet.com
- Vera Bernal, Training Operations Manager: vera.bernal@aviatnet.com

Topics:

- Plant Wireless

Received RFB:

- RF Fundamentals

Submitted Bid:

- RF Fundamentals

Notes:

- Delivered RF Fundamentals Training.

11.2 Besser Associates

Besser Associates
650 Castro Street
Suite 120-225
Mountain View, CA 94041
(650) 949-3300
https://www.besserassociates.com/

Individual Contacts:

- Annie Wong: awong@besserassociates.com
- info@besserassociates.com

Topics:

- Plant Wireless
- Telco Wireless

Received RFB:

- RF Fundamentals
- Telco Wireless

Submitted Bid:

Notes:

- Communications.
- Specific courses include: LTE/WiMAX wireless networks, RF Techniques, GSM, Analog & Digital Signals, and Wireless LAN.

11.3 BreakThru Training Solutions (BTS)

BreakThru Training Solutions (BTS)
Main Office
21800 Oxnard Street
Suite 460
Woodland Hills, CA 91367
Telephone: (816) 584-8177, ext. 771
Fax: (501) 632-1151
http://www.btstraining.com

Individual Contact:

- Christopher Kehoe: (816) 584-8177, ext. 774; ckehoe@btstraining.com
- Brittney Cope: (816) 584-8177, ext. 778; bcope@btstraining.com

Topics:

- Plant Wireless
- Telco Wireless
- Plant Wired
- Telco Wired
- IP Networking

Received RFB:

- RF Fundamentals
- RF System Design
- Optical Fiber
- Plant Wired Core / Serial / xDSL
- IP Networking
- Telco Wireless

Submitted Bid:

- RF System Design

Notes:

- Delivered RF System Design course.

11.4 Cable AML

Cable AML
2271 W. 205th Street, Suite 101
Torrance, CA 90501
Telephone: 1-805-300-6355; 1-310-222-5599
https://cableaml.com

Individual Contacts:

- Francisco Bernues: bernues@cableaml.com
- Sunil Naik: Sunilnaik@cableaml.com
- Lourdes Perez: lperez@cableaml.com

Topics:

- Plant Wireless

Received RFB:

- RF Fundamentals

Submitted Bid:

Notes:

- "We both would be happy to provide customized training for RF Systems Fundamentals."

11.5 CellStream, Inc.

CellStream, Inc.
Plano, TX
(866) 659-1014
http://www.cellstream.com

Individual Contacts:
IP Networking, General – Andrew Walding: awalding@gmail.com

Topics:
- Plant Wireless
- Telco Wireless
- IP Networking

Received RFB:
- RF Fundamentals
- IP Networking
- Telco Wireless

Submitted Bid:
- IP Networking
- Telco Wireless

Notes:
- Delivered IP Networking course through Dashcourses.
- Have since delivered multiple IP Networking Fundamentals courses and an Advanced TCP/IP course.

11.6 ENO.com

ENO
E&A Information Services, Inc.
6 St. Charles Ct
Stafford, VA 22556 USA
(540) 720-9660
https://www.enowireless.com/

Individual Contact:

- Jim Cummings: jim@enoinstitute.com
- sales@enowireless.com

Topics:

- Plant Wireless
- Telco Wireless
- Plant Wired
- Telco Wired
- IP Networking
- Small Data Center Design for TMCs

Received RFB:

- RF Fundamentals
- Plant Wired Core / Serial / xDSL
- IP Networking
- Telco Wireless
- Small Data Center Design for TMCs

Submitted Bid:

Notes:

11.7 Eogogics Inc

Eogogics, Inc.
333 Maple Avenue East, No. 2005
Vienna, VA 22180
1 (888) 364 6442
http://www.eogogics.com

Individual Contact:
KK Arora, President
Direct Telephone: (703) 539-5329
Main Telephone: (703) 281-3525
kk@eogogics.com
www.gogics.com,
info@eogogics.com

Topics:

- Plant Wireless
- Telco Wireless
- Plant Wired
- IP Networking

Received RFB:

- RF Fundamentals
- IP Networking
- Telco Wireless

Submitted Bid:

- IP Networking

Notes:

11.8 Institute of Electrical and Electronics Engineers Wireless Communication Engineering Technologies Certification

Institute of Electrical and Electronics Engineers Wireless Communication Engineering Technologies Certification
IEEE WCET Certification Program
IEEE Communications Society (IEEE ComSoc)
3 Park Avenue, 17th Floor
New York, NY 10016
(212) 705-8900
http://www.ieee-wcet.org/

Individual Contact:
Tara McNally
t.mcnally@comsoc.org

Topics:

- Plant Wireless
- Telco Wireless

Received RFB:

- RF Fundamentals

Submitted Bid:

Notes:

- Covers variety of wireless training.

11.9 New Instruction LLC

New Instruction LLC
615 Valley Rd
Montclair, NJ 07043
(973) 746-7010
https://newinstruction.com/

Individual Contact:
Maria Esteves
maria@newinstruction.com

Topics:

- Plant Wireless
- Plant Wired
- Telco Wired
- IP Networking
- Small Data Center Design for TMCs

Received RFB:

- RF Fundamentals
- Optical Fiber
- Plant Wired Core / Serial / xDSL
- IP Networking
- Small Data Center Design and Structured Cabling

Submitted Bid:

- Optical Fiber

Notes:

11.10 SRF Consulting

SRF Consulting
3701 Wayzata Boulevard
Suite 100
Minneapolis, MN 55416
(763) 475-0010
https://www.srfconsulting.com/

Individual Contact:
Mark Gallagher
mgallagher@srfconsulting.com

Topics:

- Plant Wireless

Received RFB:

- RF Fundamentals

Submitted Bid:

Notes:

- Contact via Susan Gallagher.

11.11 Systems & Network Training

Systems & Network Training
Robert Denholm House
Bletchingley Road
Nutfield
Surrey RH1 4HW
++44(0) 1737 821590
http://www.snt.co.uk

Individual Contact:

- Alex Thacker: alex@snt.co.uk, alexander.thacker@snt.co.uk
- info@snt.co.uk

Topics:

- Plant Wireless
- Telco Wireless
- Plant Wired
- Telco Wired
- IP Networking

Received RFB:

- RF Fundamentals
- Plant Wired Core / Serial / xDSL
- IP Networking
- Telco Wireless

Submitted Bid:

- Plant Wired Core / Serial / xDSL
- IP Networking
- Telco Wireless

Notes:

11.12 TONEX

TONEX
1400 Preston Rd., Suite 400
Plano, Texas 75093
(650) 485-4867
http://www.tonex.com

Individual Contact:
Howard J Gottlieb
Telephone: (214) 762-6673
Fax: (972) 692-6829
hgottlieb@tonex.com

Topics:

- Plant Wireless
- Telco Wireless
- Plant Wired
- Telco Wired
- IP Networking
- Small Data Center Design for TMCs

Received RFB:

- RF Fundamentals
- RF System Design
- Optical Fiber
- Plant Wired Core / Serial / xDSL
- IP Networking
- Telco Wireless
- Small Data Center Design and Structured Cabling

Submitted Bid:

- RF System Design
- Telco Wireless
- Small Data Center Design and Structured Cabling

Notes:

- Delivered Telco Wireless course.
- Provide many training courses covering most subjects for each topic with hands on activities.

11.13 Wireless Research Center

Wireless Research Center
3331 Heritage Trade Dr.
Suite 101
Wake Forest, NC 27587
Mobile phone: (919) 270-5074
https://wrc-nc.org/

Individual Contacts:

- John Swartz: john.swartz@wrc-nc.org
- Shruthi Soora: shruthi.soora@wrc-nc.org
- Jordan Stearns: jordan.stearns@wrc-nc.org

Topics:

- Plant Wireless
- Telco Wireless

Received RFB:

- RF Fundamentals

Submitted Bid:

Notes:

12 Appendix B: Request for Bids

REQUEST FOR WRITTEN BIDS	
State of Montana **LIMITED SOLICITATION FORM** **AGENCY** **Montana State University**	Solicitation Number: 421470-1403 Solicitation Title: Professional Capacity Building for Communication Systems Course Delivery – Radio Frequency (RF) Systems Fundamentals MSU Dept. Contact: Leann Koon 1-406-994-7643, leann.koon@montana.edu

Limited Solicitation is an informal procurement method for purchases over $5,000 and up to $25,000. This process is authorized by section 18-4-305, MCA, and ARM 2.5.603.

Company Name: _____

Address: _____

_____

Phone Number: _____ Fax Number: _____

Signed W-9 is required prior to any award.

Responses to this solicitation will be accepted by **MSU / Western Transportation Institute** at **P.O. Box 174250, Bozeman, MT 59717-4250**, or electronically by email at **leann.koon@montana.edu** until **5:00 PM (Bozeman time)** on **April 22, 2022.** The following documents are attached to this solicitation and will be applicable to the resultant contract: **Exhibit A Requirements and Scope of Services; Deliverables, Due Dates, Payment; Standard Terms and Conditions**; **and Exhibit B Blank Contracted Services Agreement.**

Instructions and Requirements / Scope of Services are stated on pages 3-8.

Item Description	Qty	Price
Course materials		
Customization		
Training delivery		
Travel and Instructor Materials Instructor material and travel expenses, including transportation, lodging, per diem, and incidentals, must be included and designated as such (line items) in the bid. Training provider will be responsible for instructor travel arrangements.		
Total		

Vendor Signature: _____

Additional vendor information attached: Yes _____ No _____

SEE STANDARD TERMS AND CONDITIONS ON PAGES 12 - 14.

MSU reserves the right to award a contract based on factors other than the lowest acceptable quote. MSU will review and evaluate the quotes based on price and the following factors. Vendors are required to submit the following information and responses with their bids:

Total evaluation points possible: 150

1. Section 3.1 Course Curriculum – 50 points
2. Section 3.2 Customization – Pass/Fail
3. Section 3.3 Instructor – 25 points
4. Section 3.4 Company Qualifications – 25 points
5. Section 3.5 References – Pass/Fail

COST BID – total points possible: 50

Lowest proposed price receives the maximum allotted points. All other proposals receive a percentage of the points available based on their relationship to the lowest. Example: Possible points for price are 50. Vendor A submits a price of $10,000. Vendor B submits a price of $12,000. Vendor A receives 50 points. Vendor B receives 42 points calculated as such: ($10,000/$12,000) = 83% times 50 = 42.

Scoring Criteria other than Price

Superior Response (95-100%): A superior response is an exceptional reply that completely and comprehensively meets all the requirements of the RFB. In addition, the response may cover areas not originally addressed within the RFB and/or include additional information and recommendations that would prove both valuable and beneficial to the agency.

Good Response (75-94%): A good response clearly meets all the requirements of the RFB and demonstrates in an unambiguous and concise manner a thorough knowledge and understanding of the project, with no deficiencies noted.

Fair Response (60-74%): A fair response minimally meets most requirements set forth in the RFB. The Vendor demonstrates some ability to comply with guidelines and requirements of the project, but knowledge of the subject matter is limited.

Failed Response (59% or less): A failed response does not meet the requirements set forth in the RFB. The Vendor has not demonstrated sufficient knowledge of the subject matter.

EXHIBIT A

REQUIREMENTS AND SCOPE OF SERVICES

Professional Capacity Building for Communications Systems

Phase 5

Radio Frequency (RF) Systems Fundamentals Training

1. BACKGROUND AND REQUIREMENTS

MSU is seeking to purchase the delivery of a training course in Radio Frequency (RF) Systems Fundamentals for Rural Intelligent Transportation Systems (ITS) Engineers, and the services to present such course. The course will be delivered over five days, will be customized to meet the needs of California Department of Transportation (Caltrans) engineers, and must include hands-on lab activities. It is assumed that this course will be a customization of an existing offering from a reputable training provider and will be delivered by an experienced instructor(s) with hands-on design and implementation experience in the technologies to be presented.

Rural Intelligent Transportation Systems (ITS) deployments are becoming increasingly complex to adequately address the challenges that rural transportation presents. A greater number and variety of field devices are being utilized to improve the safety and operations of rural travel. Design of communication networks between devices such as Highway Advisory Radio (HAR), Road Weather Information Systems (RWIS), Changeable Message Signs (CMS), Closed-Circuit Television (CCTV), Extinguishable Message Signs (EMS), roadway sensors, and the Transportation Management Center (TMC) that collects and responds to the information is a key factor in the successful implementation of such field devices.

With any advancing technology, there is a need for a skilled workforce with an advancing skill set, which in turn requires ongoing training in new technologies. To realize the full benefits of rural ITS on the transportation system, engineers as well as technicians must not only be aware of what technologies are available, but especially how to best select, implement, and maintain those technologies.

To adequately address the diverse aspects of rural ITS communications, the project and the developed curriculum have been divided into different subject areas with associated topics. **RF Systems** is a topic in the subject area of plant wireless transportation communication systems and is the focus of this solicitation.

This solicitation document defines the scope and sequence for **one course** that provides training for **RF systems fundamentals**.

The requirement is that the training course will dedicate a minimum of 25 percent of in-class time to realistic, hands-on problem solving and lab exercises, in addition to traditional classroom work.

The target audience includes field engineers and technicians who apply ITS technologies in rural areas to improve transportation safety and operations. Participants will generally be electrical engineers, electrical technicians, or other engineers with ITS design and implementation responsibilities.

A Project Technical Advisory Panel (PTAP) will work closely with the Contractor training provider to customize and facilitate the training course. The PTAP will consist of Caltrans ITS engineers and members of the Western Transportation Institute (WTI) project team.

The Course must be able to accommodate 12 students.

2. COURSE SCOPE

2.1. Description

Plant wireless communication, as applied to Rural ITS, consists of systems that are user owned and installed. A solid foundation in RF systems is essential for building successful wireless communication links. After taking this course, ITS engineers and technicians will have the fundamental skills and knowledge necessary to design, implement, and maintain wireless communication links with RF technology.

2.2. Participant Prerequisites

Basic electrical engineering skills or relevant experience. Participants will generally be electrical engineers, electrical technicians or other engineers with ITS design and implementation responsibilities.

2.3. Duration

Five (5) days = 40 hours

2.4. Method of Presentation

Instructor-led classroom and hands-on laboratory activities.

A minimum of 25 percent of in-class time will be dedicated to realistic, hands-on problem-solving and lab exercises, in addition to traditional classroom work.

2.5. Learning Objectives

Note: It is expected that the contractor will enhance and customize an existing course and not develop a new course from scratch based on these objectives. The procured course must, at a minimum, include the following objectives for RF systems design and plant wireless core.

2.5.1. Radio Frequency (RF) Systems and Plant Wireless Core

Basic knowledge of radio frequency communication is necessary for designing and building successful wireless communication links. For example, with the availability of the 4.9 GHz Public Safety band, RF systems may be an important way to connect multiple ITS field elements to a Transportation Management Center (TMC).

After completing the course, the student will be able to:

- Define and explain terminology and general concepts for plant wireless communication systems.
- Compare equipment specifications for RF systems.
- Select appropriate equipment for the site and system requirements (e.g., filters, power dividers, combiners, directional couplers).
- Evaluate tower and antenna site requirements, including availability of existing towers, tower structure (e.g., self-supporting or guyed), and potential antenna sharing.
- Calculate a link budget allowing for RF power, bandwidth, bit error rate, and channel noise among other variables.
- Calculate system losses due to path, system, and obstructions (i.e., transmission line loss, connector losses, path loss, and/or combiner loss).
- Evaluate the effects of fading using statistical fading models and distance-power (path loss) relationships in different propagation environments.
- Calculate path-related impairment such as the effects of outdoor terrain and structures on signal propagation.
- Analyze antenna polarization mismatch and apply the Power Loss Factor.
- Determine and apply antenna parameters such as antenna type and size, antenna patterns and polarization, gain, gain pattern, Effective (or Equivalent) Radiated Power (ERP), receive and transmit diversity, and proper installation to provide adequate coverage, mitigate interference, and reuse frequency.
- Optimize coverage of a radio system using propagation analysis tools such as ComStudy, and appropriate coverage calculation and verification techniques.
- Determine appropriate antenna spacing using adaptive antenna methods and techniques.
- Develop a block diagram of a radio system showing the location of all RF units in the system.
- Perform and interpret RF system measurements, and utilize site survey techniques, using test equipment such as network analyzers, spectrum analyzers, and time domain reflectometers (TDR). Example tests and evaluations include but are not limited to the following:
    - ERP
    - Received Signal Strength Indication (RSSI)
    - Noise Figure/Factor (NF)
    - Noise temperature
    - Receiver sensitivity
    - Sources and impact of external noise

  - Signal-to-noise ratio (S/N)
  - Co-channel and adjacent channel interference analysis
  - Intermodulation interference
- Use computer tools to evaluate radio links and perform propagation studies.
- Rack equipment and properly install waveguide/cabling according to best practices.
- Maintain and repair equipment according to system manufacturer, FCC and Caltrans guidelines.
- Evaluate the pros and cons of common alternatives.

2.6. Course Materials

The vendor will provide a description of procedure for how and when content and materials for courses are revised, updated and customized. Also include an explanation of how and when new courses are developed, and old courses are removed from the catalog.

Student materials, instructor guide, and lab manual shall be in full color and appropriately bound.

Contractor will prepare and ship student materials for 12 students plus two additional copies, for a total of 14.

The PTAP (Caltrans) and the project team (WTI) shall each retain one official copy of student materials, instructor guide, lab manual, and assessment tools for the project records.

3. REQUIRED QUALIFICATIONS

3.1. Curriculum (50 points)

This course on RF systems fundamentals shall address the topics including but not limited to, those listed in section 2.5 Learning Objectives (Radio Frequency (RF) Systems and Plant Wireless Core). The course will consist of at least 25 percent hands-on, relevant, and realistic laboratory activities / exercises.

The Vendor will provide the following with the bid submission:

- Course description, learning objectives, method of presentation, course length, amount and type of hands-on and laboratory activities, course size, and description of student materials.
- A previously developed training module or chapter on a related topic with all materials that demonstrates depth of material and presentation style. Include a revision history for the training module or chapter.
- List of equipment provided by the contractor that will be used to conduct the course and a description of intended use.

- List and description of specific hands-on and laboratory activities. Such activities might include:
  - Calculate link budgets
  - Calculate system losses
  - Install connectors
  - Install ground kits
  - Exothermic welding
  - Use a spectrum analyzer to measure RSL
  - Use a power meter to measure Tx Power
  - Select appropriate equipment for site and system requirements

3.2. Customization (Pass / Fail)

The training course will be relevant and applicable to the target audience as demonstrated with content and materials that address rural Intelligent Transportation Systems (ITS) topics and problems. The contractor will indicate to what extent customization is done for pre-existing course outlines and if applicable, provide a concise explanation of how course customization would be accomplished.

3.3. Instructor(s) (25 points)

The course will be taught by an instructor(s) with at least 10 years of real-world engineering experience in designing and implementing communications systems using RF technology. The instructor(s) must be knowledgeable and current in using RF and wireless communication technologies and demonstrate the ability to adapt course materials to the knowledge, interest, and skill level of the students. It is envisioned that the course will be taught by a single instructor. However, this does not preclude the possibility of multiple, qualified individuals team-teaching the course.

The Vendor will provide the following with the bid submission:

- A resume and biography for the instructor(s) who will be teaching the course which clearly lists and describes his / her history of industry design, implementation, and training experience in communications technology with an emphasis on RF and plant wireless technologies.
- A list, description, and methodology of courses taught by the instructor(s) in the previous three years. Include a description of the students taking these courses – typical education background, work experience, and work responsibility.

3.4. Company Qualifications (25 points)

The Vendor must demonstrate a successful history of a minimum of five years conducting training in RF and plant wireless technologies.

The Vendor will submit the following with the bid:

- A summary of company qualifications sufficient to demonstrate the company's capabilities, experience, staff, and instructors. Include the

length of time in business offering communications training, making note of length of time in business facilitating RF systems engineering training.
- An explanation of how the contractor "trains the trainer" in preparation for conducting the contractor's courses.
- List of clients from the previous three years, what courses were taught for those clients and type of customization if applicable, and the names of the instructors for those courses.

3.5. References (Pass / Fail)

The Vendor will provide a list of at least three (3) references specific to RF systems engineering training. References should include information that describes the type of services performed, type and level of customization if applicable, company name, location where the services were provided, contact person(s), and contact person's current telephone number and email address.

3.6. Location and Date

Contractor must be available to deliver the course October 3-7, 2022, October 10-14, 2022, October 17-21, 2022, or October 24-28, 2022, at the California Department of Transportation's Sacramento Regional Transportation Management Center in Rancho Cordova, California, or Caltrans' Ron LeCroix Training Center in Woodland, California. An alternate site in northern or central California may be considered. The specific date and location will be agreed to with MSU and the contractor.

Table 12: Deliverables, Due Dates, and Payment for the Scope of Work in the RFB.

Deliverables, Due Dates, and Payment

Contractor will invoice for a refundable deposit upon contract execution. The remaining balance will be invoiced by the contractor upon completion of the final deliverable (overall course evaluation).

Deliverable	Due Date	Acceptance Process
1. Course outline • Input from the PTAP will be incorporated. • Will include description, learning objectives, method of instruction, course length, and lab activities.	**June 8th, 2022, or before**	Course outline will be approved by the PTAP.
2. Course materials drafts (RF Systems Design Fundamentals) • Draft student materials - Student materials will be the primary instructional materials for the course. These materials will be prepared for students in the form of a workbook and will consist of primary course content and supplementary content materials. Student materials will be suitable for binding as well as electronic presentation. Topics shall include those listed as learning objectives in the Course Scope. • Draft instructor guide - An instructor guide will be prepared to guide the instructor in presentation of the course based on the content of the student materials. In addition to student materials, notes, discussion points, and instructional methodology guides will be prepared for course instructors. • Draft assessment tools - Formal and informal assessment tools will be prepared in conjunction with the student materials and instructor guides. Quizzes, tests, and open-ended problem-solving activities will be considered as primary assessment tools. Answers may be provided for objective questions and sample responses and rubrics will	**July 20th, 2022**	Draft versions of course materials will be reviewed and approved by the PTAP.

Deliverable	Due Date	Acceptance Process
be included to assist in assessing open-ended problem-solving activities. General course evaluation instruments will be included. • Draft hands-on activities/lab manual - Hands-on activities will be developed to supplement course content where appropriate and as described in the learning objectives section of the Course Scope. These activities will be compiled into a lab manual for optional use with the course. To promote flexibility in presentation and duration of the course, the materials will be presented as optional or supplementary. In addition to hands-on, in-class activities, other activities will be considered for inclusion such as field trips to deployments or product research activities.		
3. Final course materials	**August 17th, 2022**	Final course content and materials will be approved by the PTAP.
4. Equipment list - A list of equipment to be used in the course including the designated party responsible for supplying each piece.	**August 31st, 2022**	Equipment list will be confirmed and finalized by the contractor, the instructor if different, and the PTAP.
5. Course logistics – location, facilities, start and end times, student enrollment, instructor contact information, printed materials.	**August 31st, 2022**	Course logistics will be confirmed and finalized with the contractor, the instructor if different, and the PTAP.

Deliverable	Due Date	Acceptance Process
6. **One-hour dry run training session** – the course instructor will present over the telephone or via WebEx a one-hour preview session of the course to the PTAP and a potential student. • Session will include description or demonstration of at least one hands-on activity.	**Week of September 12th, 2022**	PTAP will approve the pedagogy and the amount and level of hands-on/laboratory activities intended for the course delivery.
7. **Course delivery**	**One of the following weeks:** **Oct. 3–7, 2022** **Oct. 10–14, 2022** **Oct. 17–21, 2022** **Oct. 24-28, 2022**	Contractor shall deliver five days of training as developed. The training shall be at the Caltrans Sacramento Regional Transportation Management Center or Caltrans' Ron LeCroix Training Center (or alternate location) for up to 12 students.
8. **Student assessment**	During and at the conclusion of course delivery	Students will be evaluated to measure the effectiveness of the training in meeting the established learning objectives.
9. **Course and instructor evaluation by students**	Immediately upon completion of course	Contractor, with input from the PTAP, will develop and administer a course and instructor

Deliverable	Due Date	Acceptance Process
		evaluation to the students.
10. Overall course evaluation	1 week after course completion	Together, the contractor, instructor if different, and the PTAP will discuss and appraise the overall course, instructor, and student learning.

13 Appendix C: Radio Frequency (RF) Fundamentals Training Agenda – October 2022

Aviat NETWORKS

Radio Frequency (RF) Fundamentals Training

Agenda – October 2022

Table 13: Day 1 Agenda for RF Fundamentals Training.

Day 1		
Time	**Topic**	**Sub-topics**
9:00-9:15	**Introduction and agenda review**	
9:15-10:30	**Microwave Theory and System Architecture**	• Introduction to Wireless Communications Systems • RF and Microwave Frequencies • Microwave Spectrum Management • Microwave system parameters
10:30-10:45	**Break**	
10:45-12:00	**Microwave Theory and System Architecture (Continued)**	• Microwave system architecture
12:00-1:00	**Lunch**	
1:00-2:15	**Modulation and Demodulation**	• Bandwidth, Modulation, and Capacity • Example Microwave Specifications • Adaptive Coding and Modulation (ACM) • Automatic Transmit Power Control (ATPC)
2:15-2:30	**Break**	
2:30-4:00	**Microwave Radio Configuration Lab**	• Microwave Graphical User Interface (GUI) • Reports and Configuration Management • Initial Configuration Steps • Microwave Radio Link Configuration
4:00-4:30	**Daily Wrap-up/Summary**	

Table 14: Day 2 Agenda for RF Fundamentals Training.

Day 2		
Time	**Topic**	**Sub-topics**
9:00-9:15	**Introduction and agenda review**	
9:15-10:30	**Microwave Radio Configuration Lab (Continued)**	• Radio Link Performance Screens • Radio Link History • Alarms and Alarm history
10:30-10:45	**Break**	
10:45-12:00	**Antennas and Waveguides**	• Radio Wave Propagation in the Atmosphere • Refraction • Rain Attenuation • Interference
12:00-1:00	**Lunch**	
1:00-2:15	**Radio Wave Propagation**	• Radio Wave Propagation in the Atmosphere • Refraction • Rain Attenuation • Interference
2:15-2:30	**Break**	
2:30-4:00	**Protection and Diversity**	• Hot Standby • Space Diversity • Frequency Diversity • Ring Protection
4:00-4:30	**Daily Wrap-up/Summary**	

Table 15: Day 3 Agenda for RF Fundamentals Training.

Day 3		
Time	**Topic**	**Sub-topics**
9:00-9:15	**Introduction and agenda review**	
9:15-10:30	**Microwave Path Design**	• Link Budgeting • 5 Nines • Path Design software • Path Profiles
10:30-10:45	**Break**	
10:45-12:00	**Microwave Path Design Lab**	• Aviatcloud Path design tool
12:00-1:00	**Lunch**	
1:00-2:15	**Telecom Site Preparation**	• Site Surveys • Tower Types • Site Grounding • Coax Cable Preparation
2:15-2:30	**Break**	
2:30-4:00	**Coax cable Connector Lab**	• Coax Cable Connector lab
4:00-4:30	**Daily Wrap-up/Summary**	

Table 16: Day 4 Agenda for RF Fundamentals Training.

Day 4		
Time	**Topic**	**Sub-topics**
9:00-9:15	**Introduction and agenda review**	
9:15-10:30	**Microwave Radio Data Transport**	• Time Division Multiplexing (TDM) • North American Digital Hierarchy • Ethernet • VLANs
10:30-10:45	**Break**	
10:45-12:00	**Microwave Radio Data Transport**	• Quality of Service • Link Aggregation • Ethernet Ring Protection (ERP) • L3 and MPLS
12:00-1:00	**Lunch**	
1:00-2:15	**Microwave Radio Data Transport Lab**	• TDM Configuration Lab • L2 and VLAN Configuration Lab
2:15-2:30	**Break**	
2:30-4:00	**Microwave Radio Data Transport Lab**	• QoS Lab • Ethernet Performance Monitoring Lab
4:00-4:30	**Daily Wrap-up/Summary**	

Table 17: Day 5 Agenda for RF Fundamentals Training.

Day 5		
Time	**Topic**	**Sub-topics**
9:00-9:15	**Introduction and agenda review**	
9:15-10:30	**Microwave Radio Element Management**	• Data Connectivity Network
10:30-10:45	**Break**	
10:45-12:00	**Microwave System Management**	• SNMP • Deploying Devices • Managing Devices
12:00-1:00	**Lunch**	
1:00-2:15	**Microwave System Management**	• Fault Management • Configuration Management • Accounting Management • Performance Management • Security Management
2:15-2:30	**Break**	
2:30-4:00	**Microwave System Management Lab**	• SNMP Lab
4:00-4:30	**Daily Wrap-up/Summary**	

14 Appendix D: WTI Course and Instructor Evaluation Form

Course and Instructor Evaluation

Course: *Radio Frequency (RF) Fundamentals Training* Professional Capacity Building for Communications	**Instructor:** Jonathan David Aviat Networks
Training Location: Sacramento Regional Transportation Management Center, Rancho Cordova, California	**Date:** October 24 -28, 2022
Student Name (*optional*):	**Caltrans District (*optional*):**

Thank you for participating in the *Radio Frequency (RF) Fundamentals Training* course presented by Aviat Networks, the California Department of Transportation, and the Western Transportation Institute. We are planning to offer another communications training course in the future and need your feedback to make it as relevant and practical as possible. Please take a few moments to complete this evaluation of the *Radio Frequency (RF) Fundamentals Training* course.

1. **Please evaluate the instructor and circle one rating for each question below.**

Instructor	Excellent	Very Good	Good	Fair	Poor
Knowledge of subject matter	5	4	3	2	1
Presentation skills and delivery	5	4	3	2	1
Ability to answer questions	5	4	3	2	1
How well prepared was the instructor?	5	4	3	2	1
How well did the instructor encourage questions and facilitate discussion?	5	4	3	2	1
How well did the instructor organize and manage the course to stay on task?	5	4	3	2	1
Overall rating of instructor	5	4	3	2	1

Please provide any comments: _____
_____
_____
_____

2. How likely would you be to attend another course taught by this instructor? Circle one rating.

Very Likely		Neutral		Not At All Likely
5	4	3	2	1

3. Please evaluate the *Radio Frequency (RF) Fundamentals Training* course and circle one rating for each characteristic.

Course	Excellent	Very Good	Good	Fair	Poor
Content overall	5	4	3	2	1
Subject matter	5	4	3	2	1
Level of detail	5	4	3	2	1
Instructional methodology	5	4	3	2	1
How easy was the course to understand?	5	4	3	2	1
How relevant was the course to your job?	5	4	3	2	1
Hands-on activities	5	4	3	2	1
Application to real situations	5	4	3	2	1
Presentation structure and organization	5	4	3	2	1
How well were course objectives achieved?	5	4	3	2	1
How well did the course meet your expectations?	5	4	3	2	1
How well did the course meet your needs?	5	4	3	2	1
Overall quality of course	5	4	3	2	1

Please provide any comments: _____
_____
_____
_____

4. Do you agree that the correct objectives were targeted? Circle one level of agreement.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
5	4	3	2	1

Please explain: _____
_____
_____
_____

5. How satisfied were you with the following aspects of the *Radio Frequency (RF) Fundamentals Training* course? Please circle one level of satisfaction for each category.

Aspect	Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied
Location	5	4	3	2	1
Facility/Classroom	5	4	3	2	1
Course length	5	4	3	2	1
Pace of course	5	4	3	2	1
Time of year course was offered	5	4	3	2	1

Please provide any comments: _____
_____
_____
_____

6. Would you recommend this course to others?

Definitely	Likely	Neutral	Maybe	No
5	4	3	2	1

Why or why not? _____
_____
_____
_____
_____

7. Please evaluate the course materials and circle one rating for each question below.

Materials	Excellent	Very Good	Good	Fair	Poor
Overall quality	5	4	3	2	1
Organization, flow and structure of information	5	4	3	2	1
How well did the course materials follow the course presentation?	5	4	3	2	1
Usefulness, practicality of course materials	5	4	3	2	1
How easy were the materials to understand?	5	4	3	2	1
Potential value as future reference material	5	4	3	2	1

Please provide any comments: _____
_____
_____
_____

8. **I will apply the following in my job:**

_____
_____
_____
_____

9. **I will have difficulty applying the following to my job:**

_____
_____
_____
_____

10. ***This course was offered as part of Phase 5 of the Professional Capacity Building for Communications project.*** **Based on results of the Needs Assessments conducted in Phases 1, 3, and 5 of the project, this course was chosen as part of the solution for building professional capacity in ITS communications. Did this course meet your needs and expectations for communications training in Radio Frequency (RF) Fundamentals? Please explain.**

_____
_____
_____
_____

11. **How likely would you be to participate in another training course as part of the Professional Capacity Building for Communications project?**

Very Likely		Neutral		Not At All Likely
5	4	3	2	1

12. **In what other subject areas related to ITS communications would you be interested in receiving training?**

_____
_____
_____
_____

Please provide any comments that will help improve future Professional Capacity Building for Communications training courses.

_____
_____
_____
_____
_____

Thank you for your feedback and comments!

15 Appendix E: Aviat Networks Customer Training Course Evaluation Questionnaire

Aviat NETWORKS

Customer Training Course Evaluation Questionnaire

Course Title:		**Optional:**	
Date and Location:		**Company Name:**	
Sales Order:		**Name: (Optional)**	
Instructor's Name:		**Job Title:**	

1- On a scale of 1-10, with 1 being very dissatisfied and 10 being very satisfied please rate your level of satisfaction with this training.

a.	Level of technical detail in this course	1	2	3	4	5	6	7	8	9	10	n/a
b.	Usefulness of "hands-on" training	1	2	3	4	5	6	7	8	9	10	n/a
c.	Amount of time spent on "hands-on" training	1	2	3	4	5	6	7	8	9	10	n/a
d.	Instructor's organization of materials	1	2	3	4	5	6	7	8	9	10	n/a
e.	Instructor's knowledge of product and course content	1	2	3	4	5	6	7	8	9	10	n/a
f.	Instructor's helpfulness and willingness to answer questions	1	2	3	4	5	6	7	8	9	10	n/a
g.	Instructor presented material in a clear and understandable manner	1	2	3	4	5	6	7	8	9	10	n/a
h.	Overall satisfaction for the Training	1	2	3	4	5	6	7	8	9	10	n/a
For training classes held at Aviat Networks, please answer the following questions:												
I.	Classroom facility	1	2	3	4	5	6	7	8	9	10	n/a
j.	Classroom organization	1	2	3	4	5	6	7	8	9	10	n/a
k.	Quality of training aids	1	2	3	4	5	6	7	8	9	10	n/a
l.	Usefulness of training aids	1	2	3	4	5	6	7	8	9	10	n/a

Comments: (OPTIONAL)

What did you like MOST about the class?

What additional services, improvements or courses would you like Aviat Networks to provide

Thank you for your help!

Aviat Networks | AviatCare Educate Services | Customer Training

16 Appendix F: Participant Evaluations (WTI) – RF Fundamentals Training

Overall Course Evaluation

WTI Research Team

The overall evaluation was developed by WTI and administered to the students at the conclusion of the training course. The results are below.

1. **Please evaluate the instructor and circle one rating for each question below.**

Table 18: Appendix - Number of students who rated the instructor at each level.

Instructor	Excellent 5	Very Good 4	Good 3	Fair 2	Poor 1	Average Rating
Knowledge of subject matter	10	2	0	0	0	**4.8**
Presentation skills and delivery	7	5	0	0	0	**4.6**
Ability to answer questions	9	3	0	0	0	**4.8**
How well prepared was the instructor?	5	5	2	0	0	**4.3**
How well did the instructor encourage questions and facilitate discussion?	7	5	0	0	0	**4.6**
How well did the instructor organize and manage the course to stay on task?	6	5	1	0	0	**4.4**
Overall rating of instructor	8	3	0	0	0	**4.7**

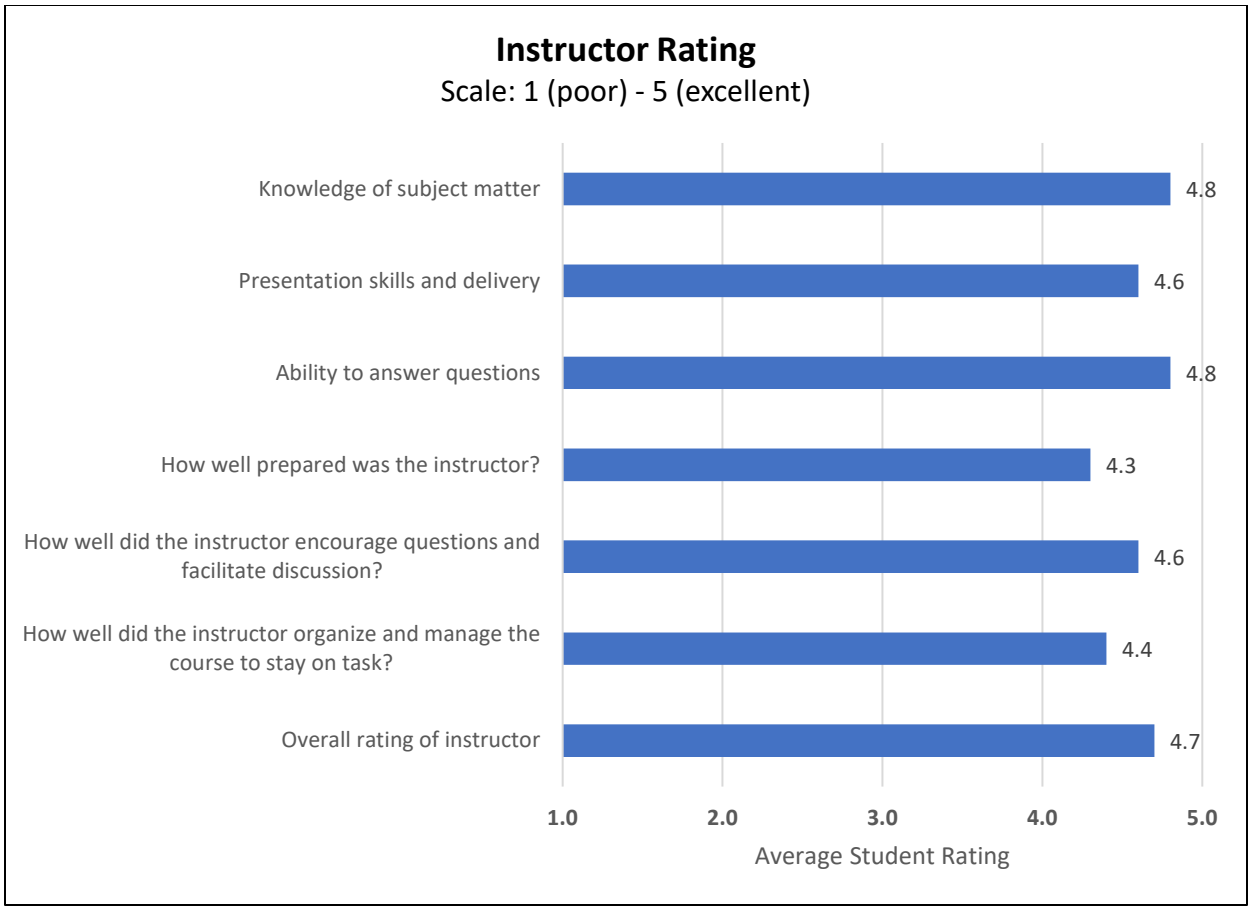

Figure 11: Appendix - Average instructor ratings.

Comments:

- *"He was an excellent instructor who had a deep knowledge of the subject."*
- *"A+ rating. Thanks Jonathan for the great class!"*
- *"Some topics moved very fast and was a lot to take in at times."*
- *"Jonathan was very knowledgeable in RF."*

2. How likely would you be to attend another course taught by this instructor? Circle one rating.

Table 19: Appendix - Number of students who would likely attend another course taught by this instructor.

	Very Likely 5	4	Neutral 3	2	Not At All Likely 1	Average Rating
How likely to attend another course by this instructor	8	2	2	0	0	**4.5**

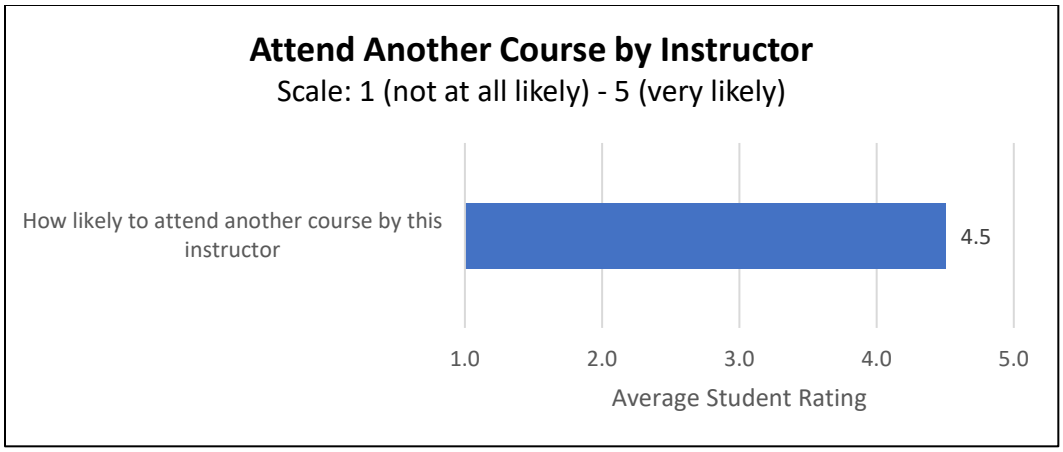

Figure 12: Appendix - How likely students would attend another course taught by this instructor.

3. Please evaluate the *Radio Frequency (RF) Fundamentals Training* course and circle one rating for each characteristic.

Table 20: Appendix - Number of students rating the course and content at each level.

Course	Excellent 5	Very Good 4	Good 3	Fair 2	Poor 1	Average Rating
Content overall	7	5	0	0	0	**4.6**
Subject matter	6	5	1	0	0	**4.4**
Level of detail	7	2	2	0	0	**4.5**
Instructional methodology	6	4	2	0	0	**4.3**
How easy was the course to understand?	4	7	1	0	0	**4.3**
How relevant was the course to your job?	3	7	2	0	0	**4.1**
Hands-on activities	5	3	2	2	0	**3.9**
Application to real situations	5	5	2	0	0	**4.3**
Presentation structure and organization	5	5	2	0	0	**4.3**
How well were course objectives achieved?	6	4	2	0	0	**4.3**
How well did the course meet your expectations?	5	3	4	0	0	**4.1**
How well did the course meet your needs?	5	3	4	0	0	**4.1**
Overall quality of course	6	5	1	0	0	**4.4**

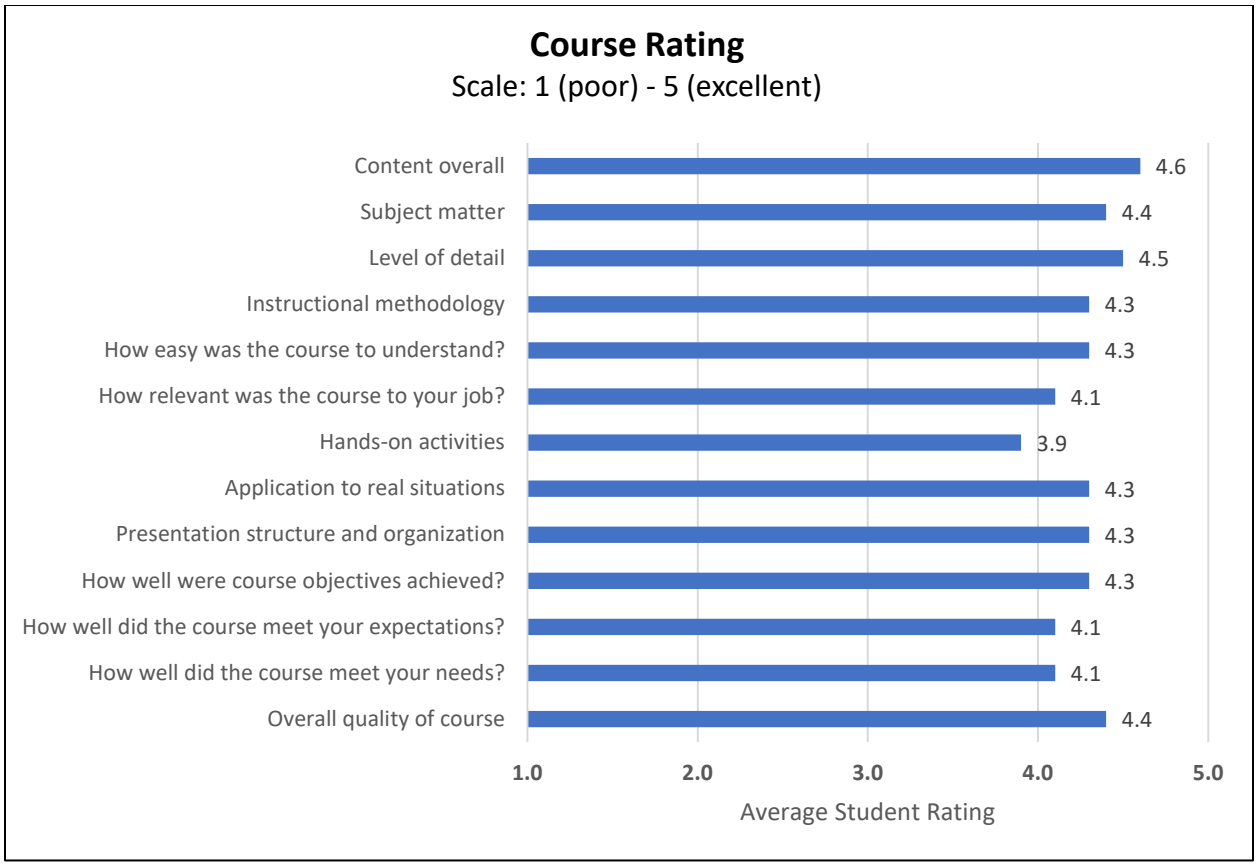

Figure 13: Appendix - Average course ratings.

Comments:

- *"The course was well laid out. Sometimes not everyone was able to do the labs."*
- *"Covered areas not of interest. Got most of what I needed in about 2 days."*
- *"I don't work with RF/microwave much on the job now but all the information is very valuable for the future."*

4. Do you agree that the correct objectives were targeted? Circle one level of agreement.

Table 21: Appendix - Number of students indicating agreement that correct objectives were targeted.

	Strongly Agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Average Rating
Agreement on target objectives	6	3	2	1	0	**4.2**

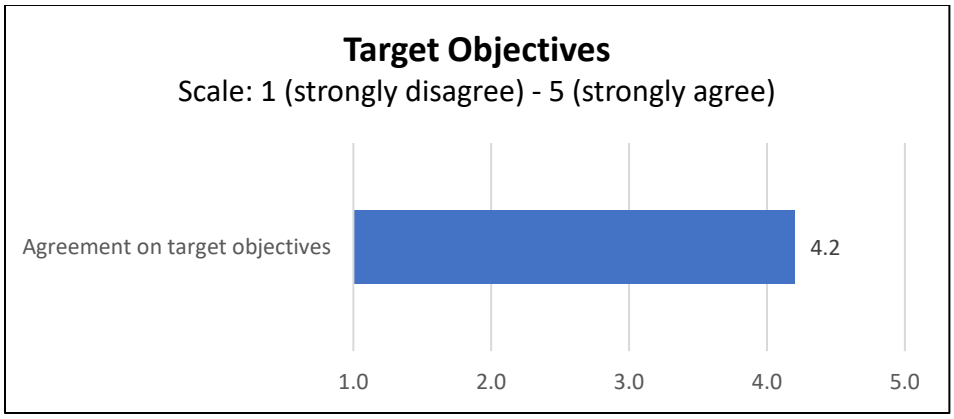

Figure 14: Appendix - Level of agreement that the correct objectives were targeted.

Please explain:

- *"The objectives were very targeted at doing regular TMS work."*
- *"Fundamentals of RF for someone like me that has little experience in that subject was made much easier to understand from this course."*
- *"Each topic was informational and applicable through real world examples."*

5. How satisfied were you with the following aspects of the *Radio Frequency (RF) Fundamentals Training* course? Please circle one level of satisfaction for each category.

Table 22: Appendix - Number of students rating level of satisfaction for different aspects of the course.

Aspect	Very Satisfied 5	Satisfied 4	Neutral 3	Dissatisfied 2	Very Dissatisfied 1	Average Rating
Location	8	4	0	0	0	**4.7**
Facility/Classroom	9	3	0	0	0	**4.8**
Course length	7	4	0	1	0	**4.4**
Pace of course	6	4	1	1	0	**4.3**
Time of year course was offered	6	5	1	0	0	**4.4**

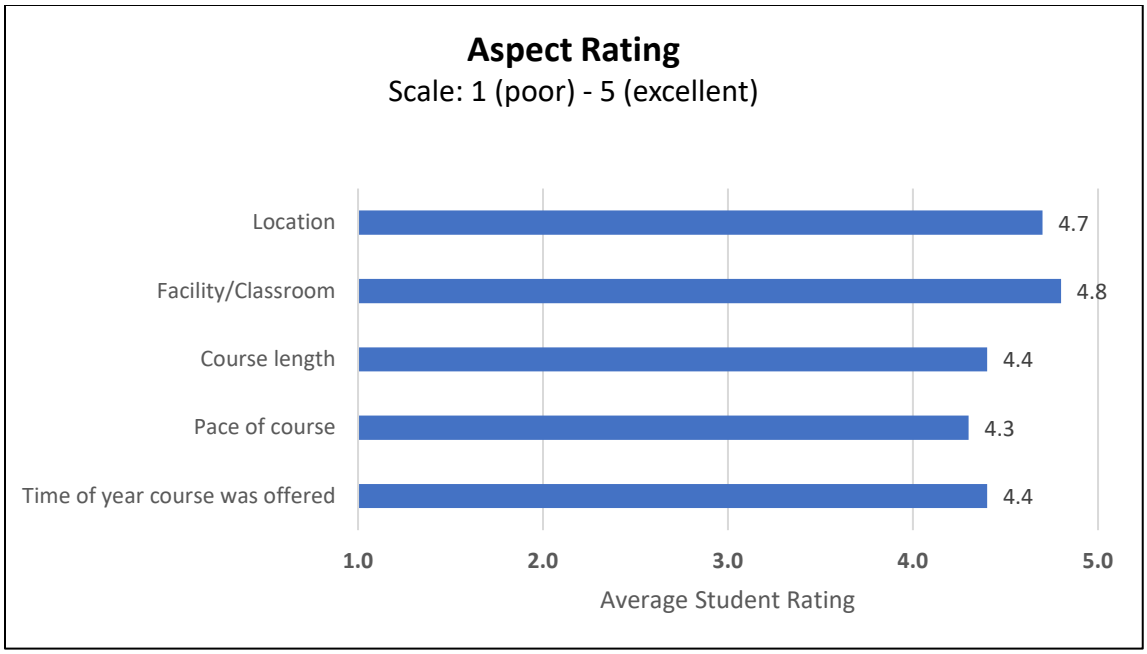

Figure 15: Appendix - Level of satisfaction with different aspects of course logistics.

Comments:

- *"Location was well lit, clean, and was easily accessible."*
- *"All good aspects, no complaints whatsoever."*
- *"Course moved very fast and could have been extended for understanding purposes."*

6. Would you recommend this course to others?

Table 23: Appendix - Number of students likely to recommend course to others.

	Definitely 5	Likely 4	Neutral 3	Maybe 2	No 1	Average Rating
Recommend to others	7	5	0	0	0	**4.6**

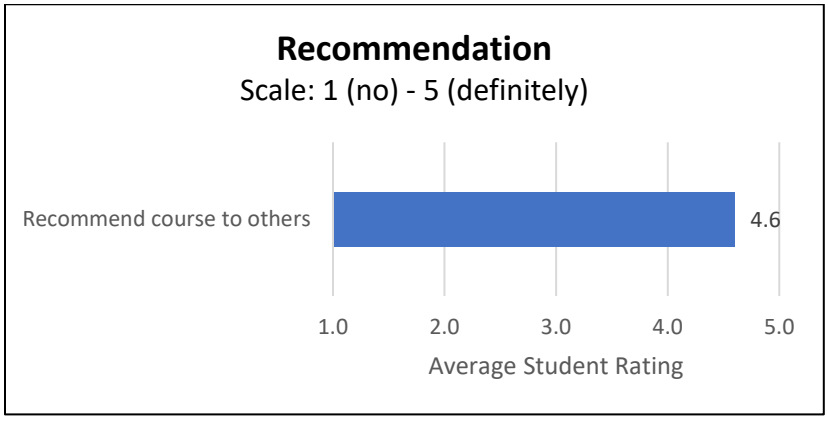

Figure 16: Appendix - How likely students were to recommend this course to others.

Why or why not?

- *"I learned a lot of material that is not covered in other courses."*
- *"If using Aviat radios. If only need RF knowledge the course could have been much shorter. More hands on design and calculations could be helpful. Testing of coax and signals also."*
- *"The core content was one worth knowing."*
- *"In D6 there are some more RF applications that others might benefit from."*
- *"Real world examples helped understand each topic along with the concepts."*

7. Please evaluate the course materials and circle one rating for each question below.

Table 24: Appendix - Number of students rating the materials at each level.

Materials	Excellent 5	Very Good 4	Good 3	Fair 2	Poor 1	Average Rating
Overall quality	5	4	3	0	0	**4.2**
Organization, flow, and structure of information	6	4	1	1	0	**4.3**
How well did the course materials follow the course presentation?	8	2	1	1	0	**4.4**
Usefulness, practicality of course materials	6	4	1	1	0	**4.3**
How easy were the materials to understand?	4	5	1	1	1	**3.8**
Potential value as future reference material	4	5	2	1	0	**4.0**

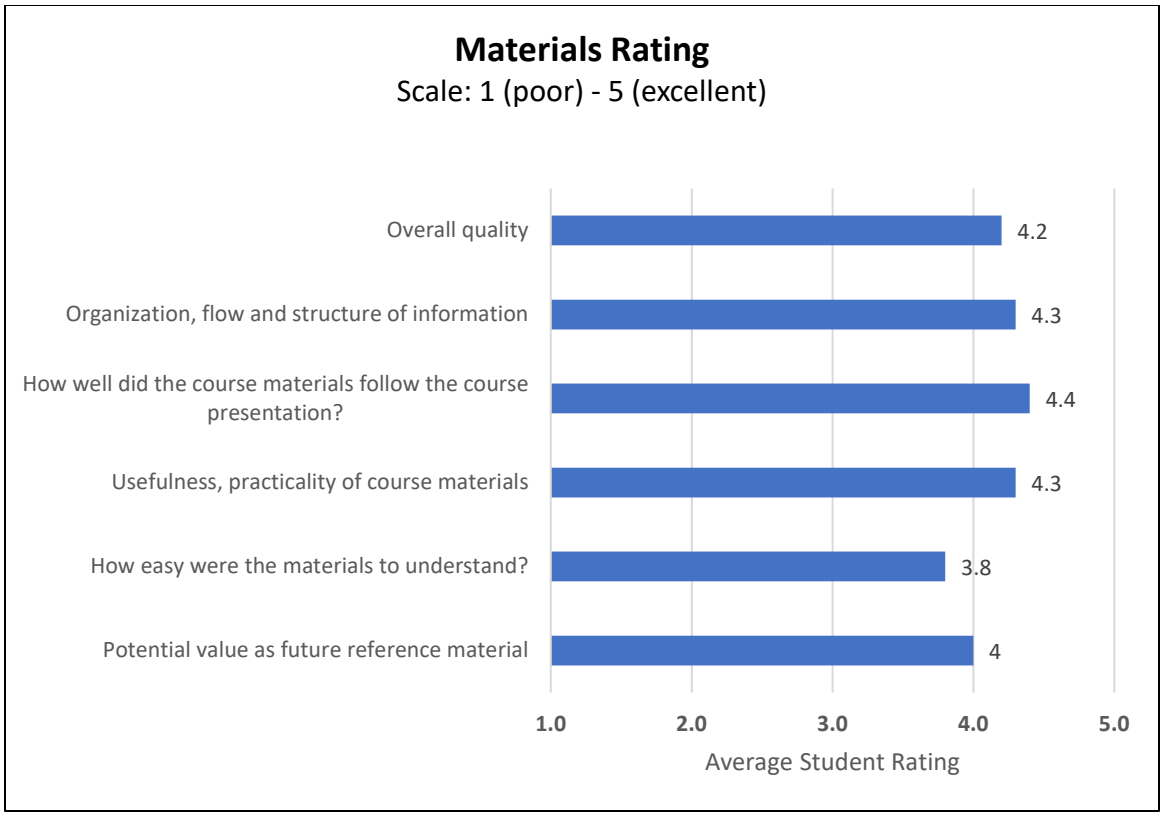

Figure 17: Appendix - Average ratings for the course materials.

Comments:

- *"The course material was very useful. I will be referring back to it in the future."*
- *"The font size of the screenshots could be bigger."*
- *"Labs hard to follow."*
- *"I will be keeping all material and notes for future reference and will be sure to share with my colleagues in D6."*

8. I will apply the following in my job:

- *"RF communication design"*
- *"Point to point communications, RF, switching and routing."*
- *"Yes sure very friendly [ ] software."*
- *"Setting up RF links, understanding modulation, basic routing/switching understanding."*
- *"Determination of path loss and site design for RF links."*
- *"SNMP"*
- *"Basic understanding of radio path and set up for install application."*
- *"RSSI dish alignment"*
- *"Honestly not much now, but for sure in the future when integrating some elements with RF. Mostly rural sites and maybe the FDWS."*
- *"SNMP Traps and monitoring, troubleshooting radio connectivity and configuration. Bandwidth and distance determinations for existing sites."*
- *"Troubleshooting RF links"*

9. I will have difficulty applying the following to my job:

- *"Easy to install and apply."*
- *"None."*
- *"The data management and general data configuring."*
- *"Some of the management options that were shown."*
- *"Same as above. Mostly future application. Not much now."*
- *"Aviat specific software and configurations given difference in radio types."*
- *"Aviat hardware knowledge."*

10. ***This course was offered as part of Phase 5 of the Professional Capacity Building for Communications project.*** **Based on results of the Needs Assessments conducted in Phases 1, 3, and 5 of the project, this course was chosen as part of the solution for building professional capacity in ITS communications. Did this course meet your needs and expectations for communications training in Radio Frequency (RF) Fundamentals? Please explain.**

- *"Yes, I learned a lot about RF links. I would like to learn more about cellular communication as well."*
- *"Yes. The frequency selection criteria and RF path loss calculations were the most useful parts of the class."*
- *"Yes. The RF microwave knowledge can be applied to different projects that might require [evolution] of different technologies."*
- *"Yes. Was a good intro for basic radio set up."*
- *"Yes, it explained the theory of RF communications and has brought a better understanding."*
- *"Yes, although I'm not too knowledgeable on these phases. I really enjoyed the course and subject material. I will use the info from the practical applications the most."*
- *"Yes, this training touched on and explained applicable real world experiences with background on how to approach deployment/[maintenance] and troubleshooting."*
- *"Yes"*

11. How likely would you be to participate in another training course as part of the Professional Capacity Building for Communications project?

Table 25: Appendix - Number of students likely to participate in another PCB training.

	Very Likely 5	4	Neutral 3	2	Not At All Likely 1	Average Rating
Participate in another training for PCB	8	3	1	0	0	4.6

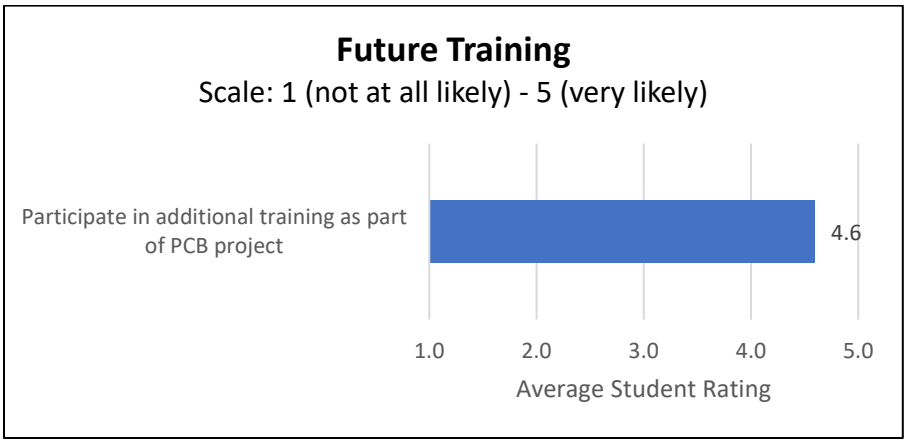

Figure 18: Appendix - Average rating for how likely students would participate in another PCB training.

12. In what other subject areas related to ITS communications would you be interested in receiving training?

- *"Fiber optic"*
- *"Cellular communication, networking/switching"*
- *"Video encoding and streaming. Network QoS."*
- *"Automation / coding"*
- *"Basic practices for equipment installs."*
- *"I am interested in POTS communication."*
- *"Fiber communications, networking, routing, switching for CT use, Statewide ATMS ??? Maybe..."*
- *"Newer smart systems for self driving cars and the like."*
- *"TCP/IP, Solar"*

Please provide any comments that will help improve future Professional Capacity Building for Communications training courses.

- *"I like the layout of this training. Lab/class work is a good setup."*
- *"Well done to Jonathan for leading this course. Instructors at his experience add tremendous practical and fundamental knowledge needed to have successful training."*
- *"Different types of radios and scenarios/hands-on troubleshooting to better understand real world expectations."*
- *"More hands on with POE antenna / radio combo units."*

17 Appendix G: Participant Evaluations (Aviat Networks) – RF Fundamentals Training

Course Evaluation
Aviat Networks

This course evaluation was administered to the students at the conclusion of the course. The results are below.

1- On a scale of 1-10, with 1 being very dissatisfied and 10 being very satisfied please rate your level of satisfaction with this training.

Table 26: Appendix - Number of students who rated the training and instructor at each level (Aviat Networks evaluation).

Question	1	2	3	4	5	6	7	8	9	10	Average Rating
Level of technical detail	0	0	0	0	0	0	1	1	1	5	**9.3**
Usefulness of "hands-on" training	0	0	0	0	1	1	0	2	2	2	**8.1**
Amount of time spent on "hands-on" training	0	0	0	0	1	1	2	1	1	2	**7.8**
Instructor's organization of materials	0	0	0	0	0	0	2	0	2	4	**9.0**
Instructor's knowledge of product, course content	0	0	0	0	0	0	0	1	0	7	**9.8**
Instructor's helpfulness, willingness to answer questions	0	0	0	0	0	0	0	0	1	7	**9.9**
Instructor presented material in a clear and understandable manner	0	0	0	0	0	0	0	0	3	5	**9.6**
Overall satisfaction for the training	0	0	0	0	0	0	0	1	2	5	**9.5**

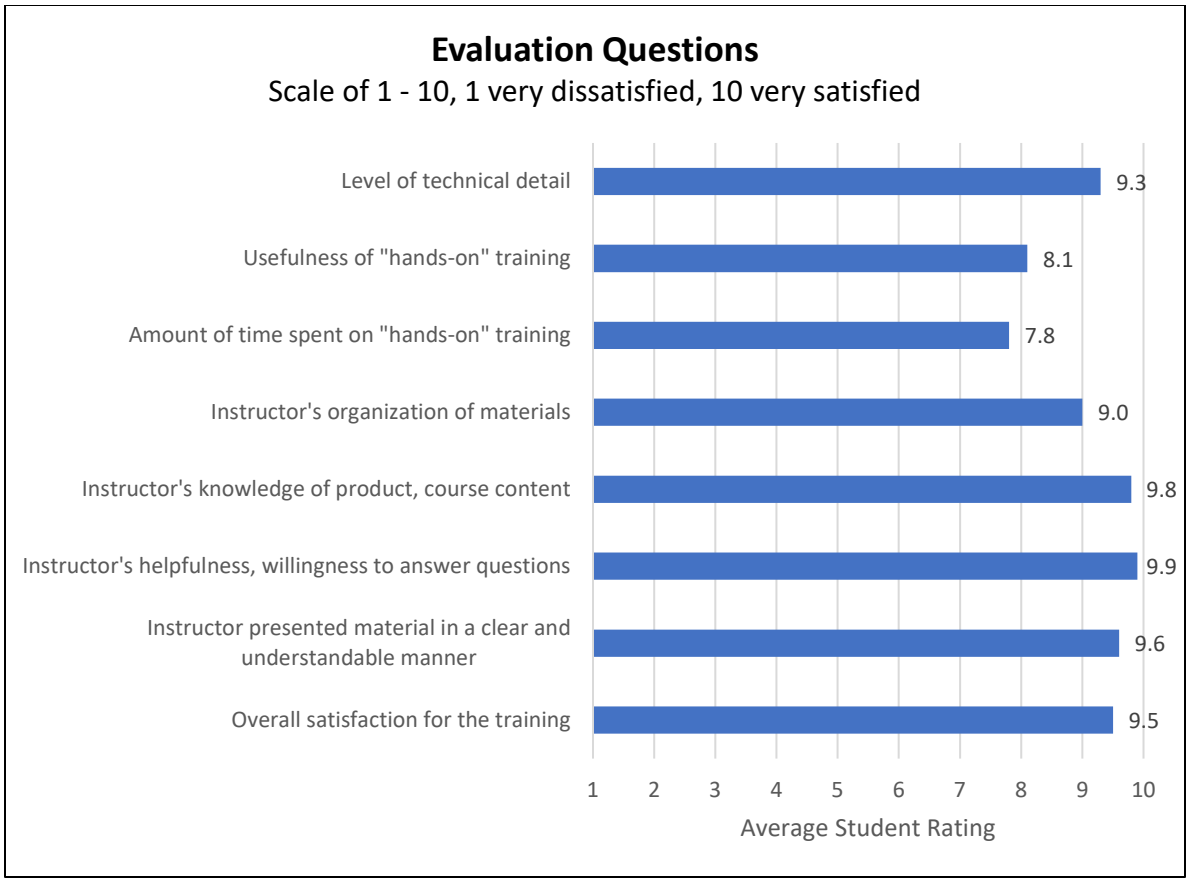

Figure 19: Appendix - Average course and instructor ratings (Aviat Networks evaluation).

Comments:

What did you like MOST about the class?

- *"The knowledge of the instructed and the ability to answer questions."*
- *"I appreciated the real-world applications and experience provided by the instructor. It placed and emphasis on what/why we're approaching things in specific ways as well as what we might see in the field."*
- *"The instructor's knowledge of the practical applications, historical and technical backgrounds, and presentation of the fundamentals were very insightful and useful."*
- *"History and the explanation of the genealogy of Microwave Radios."*
- *"Very informative"*
- *"Software"*

What additional services, improvements or courses would you like Aviat Networks to provide?

- *"For improvement, the labs were hard to understand and follow."*
- *"The course moved very quickly and would appreciate if some topics moved a bit slower."*
- *"N/A at this time. In the future I will sign up for any RF related courses though!"*
- *"More attention to designing a system and calculating a link, troubleshooting transmission lines and power levels. Having a software version of the hardware (similar to Cisco) that would allow each student to create links and test on their own machines would be helpful. Having limited hardware for people to work on slowed the process and allowed people to change others work making things more difficult."*
- *"RF equipment"*

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