FDP Cost Reimbursement Subaward

Federal Awarding Agency: U.S. Department of Transportation Federal Highway Administration

Pass-Through Entity (PTE):	**Subrecipient:**
Regents of the University of Michigan	City Of Ann Arbor
PTE PI: Henry Liu	Sub PI: Raymond Hess
PTE Federal Award No: 693JJ32150006	Subaward No: SUBK00013926
Project Title: Smart Intersections: Paving the Way for a National CAV Deployment	
Subaward Budget Period: Start: 09/29/2021 End: 09/28/2024	Amount Funded This Action (USD): $ 374,738.00
Estimated Period of Performance: Start: 09/29/2021 End: 09/28/2024	Incrementally Estimated Total (USD): $ 374,738.00

Terms and Conditions

1. PTE hereby awards a cost reimbursable subaward, (as determined by 2 CFR 200.331), to Subrecipient. The Statement of Work and budget for this Subaward are as shown in Attachment 5. In its performance of Subaward work, Subrecipient shall be an independent entity and not an employee or agent of PTE.

2. Subrecipient shall submit invoices not more often than monthly and not less frequently than quarterly for allowable costs incurred. Upon the receipt of proper invoices, the PTE agrees to process payments in accordance with this Subaward and 2 CFR 200.305. All invoices shall be submitted using Subrecipient's standard invoice, but at a minimum shall include current and cumulative costs (including cost sharing), breakdown by major cost category, Subaward number, and certification, as required in 2 CFR 200.415(a). Invoices that do not reference PTE Subaward number shall be returned to Subrecipient. Invoices and questions concerning invoice receipt or payments shall be directed to the party's Financial Contact, shown in Attachment 3A.

3. A final statement of cumulative costs incurred, including cost sharing, marked "FINAL" must be submitted to PTE's Financial Contact, as shown in Attachment 3A, not later than 60 days after each Budget Period end date. The final statement of costs shall constitute Subrecipient's final financial report.

4. All payments shall be considered provisional and are subject to adjustment within the total estimated cost in the event such adjustment is necessary as a result of an adverse audit finding against the Subrecipient.

5. Matters concerning the technical performance of this Subaward shall be directed to the appropriate party's Principal Investigator as shown in Attachments 3A and 3B. Technical reports are required as shown in Attachment 4.

6. Matters concerning the request or negotiation of any changes in the terms, conditions, or amounts cited in this Subaward, and any changes requiring prior approval, shall be directed to the PTE's Administrative Contact and the Subrecipient's Authorized Official Contact shown in Attachments 3A and 3B. Any such change made to this Subaward requires the written approval of each party's Authorized Official as shown in Attachments 3A and 3B.

7. The PTE may issue non-substantive changes to the Budget Period(s) and Budget Bilaterally. Unilateral modification shall be considered valid 14 days after receipt unless otherwise indicated by Subrecipient when sent to Subrecipient's Authorized Official Contact, as shown in Attachment 3B.

8. Each party shall be responsible for its negligent acts or omissions and the negligent acts or omissions of its employees, officers, or directors, to the extent allowed by law.

9. Either party may terminate this Subaward with 30 days written notice. Notwithstanding, if the Awarding Agency terminates the Federal Award, PTE will terminate in accordance with Awarding Agency requirements. PTE notice shall be directed to the Authorized Official Contact, and Subrecipient notice shall be directed to the Authorized Official Contact as shown in Attachments 3A and 3B. PTE shall pay Subrecipient for termination costs as allowable under Uniform Guidance, 2 CFR 200, or 45 CFR Part 75 Appendix IX, as applicable

10. By signing this Subaward, including the attachments hereto which are hereby incorporated by reference, Subrecipient certifies that it will perform the Statement of Work in accordance with the terms and conditions of this Subaward and the applicable terms of the Federal Award, including the appropriate Research Terms and Conditions ("RTCs") of the Federal Awarding Agency, as referenced in Attachment 2. The parties further agree that they intend this subaward to comply with all applicable laws, regulations, and requirements.

By an Authorized Official of the PTE:	By an Authorized Official of the Subrecipient:
Name: Ashley K. Tyler Date	Name: Date
Title: Contract Administration Senior	Title:

Attachment 1
Certifications and Assurances

Subaward Number:
SUBK00013926

Certification Regarding Lobbying (2 CFR 200.450)
By signing this Subaward, the Subrecipient Authorized Official certifies, to the best of his/her knowledge and belief, that no Federal appropriated funds have been paid or will be paid, by or on behalf of the Subrecipient, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement in accordance with 2 CFR 200.450.

If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or intending to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the Subrecipient shall complete and submit Standard Form -LLL, "Disclosure Form to Report Lobbying," to the PTE.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by 31 U.S.C. 1352. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Debarment, Suspension, and Other Responsibility Matters (2 CFR 200.214 and 2 CFR 180)
By signing this Subaward, the Subrecipient Authorized Official certifies, to the best of his/her knowledge and belief that neither the Subrecipient nor its principals are presently debarred, suspended, proposed for debarment, declared ineligible or voluntarily excluded from participation in this transaction by any federal department or agency, in accordance with 2 CFR 200.213 and 2 CFR 180.

Audit and Access to Records
Subrecipient certifies that it will provide PTE with notice of any adverse findings which impact this Subaward. Subrecipient certifies compliance with applicable provisions of 2 CFR 200.501-200.521. If Subrecipient is not required to have a Single Audit as defined by 200.501, Awarding Agency requirements, or the Single Audit Act, then Subrecipient will provide notice of the completion of any required audits and will provide access to such audits upon request. Subrecipient will provide access to records as required by parts 2 CFR 200.337 and 200.338 as applicable.

Program for Enhancement of Contractor Employee Protections (41 U.S.C 4712)
Subrecipient is hereby notified that they are required to: inform their employees working on any federal award that they are subject to the whistleblower rights and remedies of the program; inform their employees in writing of employee whistleblower protections under 41 U.S.C §4712 in the predominant native language of the workforce; and include such requirements in any agreement made with a subcontractor or subgrantee.

The Subrecipient shall require that the language of the certifications above in this Attachment 1 be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

Use of Name
Neither party shall use the other party's name, trademarks, or other logos in any publicity, advertising, or news release without the prior written approval of an authorized representative of that party. The parties agree that each party may use factual information regarding the existence and purpose of the relationship that is the subject of this Subaward for legitimate business purposes, to satisfy any reporting and funding obligations, or as required by applicable law or regulation without written permission from the other party. In any such statement, the relationship of the parties shall be accurately and appropriately described.

Prohibition on Certain Telecommunication and Video Surveillance Services or Equipment
Pursuant to 2 CFR 200.216, Subrecipient will not obligate or expend funds received under this Subaward to: (1) procure or obtain; (2) extend or renew a contract to procure or obtain; or (3) enter into a contract (or extend or renew a contract) to procure or obtain equipment, services, or systems that uses covered telecommunications equipment or services (as described in Public Law 115-232, section 889) as a substantial or essential component of any system, or as a critical technology as part of any system.

Attachment 2
Federal Award Terms and Conditions

Subaward Number: SUBK00013926

Required Data Elements

The data elements required by Uniform Guidance are incorporated: as entered.

Awarding Agency Institute (If Applicable):

Federal Award Issue Date	FAIN	Assistance Listing No.
09/29/21	693JJ32150006	20.200

Assistance Listing Program Title (ALPT): Highway Research and Development Program

Key Personnel Per NOA: Refer to attached NOA

This Subaward Is:

- [x] Research & Development
- [x] Subject to FFATA

General Terms and Conditions

By signing this Subaward, Subrecipient agrees to the following:

1. To abide by the conditions on activities and restrictions on expenditure of federal funds in appropriations acts that are applicable to this Subaward to the extent those restrictions are pertinent. This includes any recent legislation noted on the Federal Awarding Agency's website:
   Refer to attached award notice
2. 2 CFR 200
3. The Federal Awarding Agency's grants policy guidance, including addenda in effect as of the beginning date of the period of performance or as amended found at:
   Refer to attached award notice
4. Research Terms and Conditions, including any Federal Awarding Agency's Specific Requirements found at:
   Refer to attached award notice except for the following :
   a. No-cost extensions require the written approval of the PTE. Any requests for a no-cost extension shall be directed to the Authorized Official Contact shown in Attachment 3A, not less than 30 days prior to the desired effective date of the requested change.
   b. Any payment mechanisms and financial reporting requirements described in the applicable Federal Awarding Agency Terms and Conditions and Agency-Specific Requirements are replaced with Terms and Conditions (1) through (4) of this Subaward; and
   c. Any prior approvals are to be sought from the PTE and not the Federal Awarding Agency.
   d. Title to equipment as defined in 2 CFR 200.1 that is purchased or fabricated with research funds or Subrecipient cost sharing funds, as direct costs of the project or program, shall vest in the Subrecipient subject to the conditions specified in 2 CFR 200.313.
   e. Prior approval must be sought for a change in Subrecipient PI or change in Key Personnel (defined as listed on the NOA).
5. Treatment of program income: Additive

Special Terms and Conditions:

Data Sharing and Access:
Subrecipient agrees to comply with the Federal Awarding Agency's data sharing and/or access requirements as reflected in the NOA or the Federal Awarding Agency's standard terms and conditions as referenced in General Terms and Conditions 1-4 above.
No additional requirements

Data Rights:
Subrecipient grants to PTE the right to use data created in the performance of this Subaward solely for the purpose of and only to the extent required to meet PTE's obligations to the Federal Government under its PTE Federal Award.

Copyrights:
Subrecipient Grants to PTE an irrevocable, royalty-free, non-transferable, non-exclusive right and license to use, reproduce, make derivative works, display, and perform publicly any copyrights or copyrighted material (including any computer software and its documentation and/or databases) first developed and delivered under this Subaward solely for the purpose of and only to the extent required to meet PTE's obligations to the Federal Government under its PTE Federal Award.

Subrecipient grants to PTE the right to use any written progress reports and deliverables created under this Subaward solely for the purpose of and only to the extent required to meet PTE's obligations to the Federal Government under its Federal Award.

Promoting Objectivity in Research (COI):
Subrecipient must designate herein which entity's Financial Conflicts of Interest policy (COI) will apply: Subrecipient

If applying its own COI policy, by execution of this Subaward, Subrecipient certifies that its policy complies with the requirements of the relevant Federal Awarding Agency as identified herein: DOT Federal Highway Administration

Subrecipient shall report any financial conflict of interest to PTE's Administrative Representative or COI contact, as designated on Attachment 3A. Any financial conflicts of interest identified shall, when applicable, subsequently be reported to Federal Awarding Agency. Such report shall be made before expenditure of funds authorized in this Subaward and within 45 days of any subsequently identified COI.

Work Involving Human or Vertebrate Animals (Select Applicable Options)

☒ No Human or Vertebrate Animals

This section left intentionally blank.

Human Subjects Data (Select One) Not Applicable

This section left intentionally blank

This section left intentionally blank

Additional Terms

1. The PTE Federal Award terms and conditions are applicable to this Subaward; the Notice of Award ("NOA") is provided within Attachment 6.

2. Applicant Identifier 21-PAF00320, as submitted in response to Funding Opportunity Number 693JJ320NF00010, is incorporated herein by reference, as applicable.

Attachment 3A
Pass-Through Entity (PTE) Contacts

Subaward Number: SUBK00013926

PTE Information

Entity Name: Regents of the University of Michigan

Legal Address: 3003 South State Street
Ann Arbor, Michigan 48109

Website: https://umich.edu

PTE Contacts

Central Email: subcontracts@umich.edu

Principal Investigator Name: Henry Liu

Email: henryliu@umich.edu Telephone Number: 734-764-4354

Administrative Contact Name: Ashley K. Tyler, Contract Administration Senior

Email: tyleras@umich.edu Telephone Number: 734-764-8256

COI Contact email (if different to above):

Financial Contact Name: Office of Contract Administration, Accounting Team

Email: subcontracts.accounting@umich.edu Telephone Number: 734-763-3193

Email invoices? (●) Yes ( ) No Invoice email (if different): subcontract.invoices@umich.edu

Authorized Official Name: Peter J. Gerard, Contract Administration Assistant Director

Email: subcontracts@umich.edu Telephone Number: 734-763-3193

PI Address:

Civil & Environmental Engr
2116 GGB
Ann Arbor, MI 48109-2125

Administrative Address:

Sponsored Programs - Office of Contract Administration
5000 Wolverine Tower
3003 South State Street
Ann Arbor, Michigan 48109-1287

Invoice Address:

Email Only: subcontract.invoices@umich.edu

Attachment 3B

Subrecipient Contacts

Subaward Number: SUBK00013926

Subrecipient Information for FFATA reporting

Entity's DUNS Name:

EIN No.:

Institution Type:

DUNS:

Currently registered in SAM.gov: ◯ Yes ◯ No

Exempt from reporting executive compensation: ◯ Yes ◯ No *(if no, complete 3Bpg2)*

Parent DUNS:

This section for U.S. Entities:

Zip Code Look-up

Congressional District:

Zip Code+4:

Place of Performance Address

Subrecipient Contacts

Central Email:

Website:

Principal Investigator Name: Raymond Hess

Email:

Telephone Number:

Administrative Contact Name:

Email:

Telephone Number:

Financial Contact Name:

Email:

Telephone Number:

Invoice/Payment Email:

Authorized Official Name:

Email:

Telephone Number:

Legal Address:

Administrative Address:

Payment Address:

Attachment 3B-2

Highest Compensated Officers

Subaward Number: SUBK00013926

Subrecipient:

Institution Name: City Of Ann Arbor

PI Name: Raymond Hess

Highest Compensated Officers

The names and total compensation of the five most highly compensated officers of the entity(ies) must be listed if the entity in the preceding fiscal year received 80 percent or more of its annual gross revenues in Federal awards; and $25,000,000 or more in annual gross revenues from Federal awards; and the public does not have access to this information about the compensation of the senior executives of the entity through periodic reports filed under section 13(a) or 15(d) of the Securities Exchange Act of 1934 (15 U.S.C. §§ 78m(a), 78o(d)) or section 6104 of the Internal Revenue Code of 1986. See FFATA § 2(b)(1) Internal Revenue Code of 1986.

Officer 1 Name:

Officer 1 Compensation:

Officer 2 Name:

Officer 2 Compensation:

Officer 3 Name:

Officer 3 Compensation:

Officer 4 Name:

Officer 4 Compensation:

Officer 5 Name:

Officer 5 Compensation:

Attachment 4
Reporting and Prior Approval Terms

Subaward Number: SUBK00013926

Subrecipient agrees to submit the following reports (PTE contacts are identified in Attachment 3A):

Technical Reports:

☐ Monthly technical/progress reports will be submitted to the PTE's Administrative Contact within 15 days of of the end of the month.

☐ Quarterly technical/progress reports will be submitted within 30 days after the end of each project quarter to the PTE's Administrative Contact.

☐ Annual technical / progress reports will be submitted within 60 days prior to the end of each budget period to the PTE's Administrative Contact. Such report shall also include a detailed budget for the next Budget Period, updated other support for key personnel, certification of appropriate education in the conduct of human subject research of any new key personnel, and annual IRB or IACUC approval, if applicable.

☐ A Final technical/progress report will be submitted to the PTE's Administrative Contact within 60 days of the end of the Project Period or after termination of this award, whichever comes first.

■ Technical/progress reports on the project as may be required by PTE's Principal Investigator in order for the PTE to satisfy its reporting obligations to the Federal Awarding Agency.

Prior Approvals:

Carryover:

Carryover is restricted for this subaward by the: Federal Awarding Agency

Carryover instructions and requirements are as stated by the Federal Awarding Agency guidance or as shown below.

Submit carryover requests to the Administrative Contact.

Other Reports:

■ In accordance with 37 CFR 401.14, Subrecipient agrees to notify both the Federal Awarding Agency via iEdison and PTE's Financial Contact within 60 days after Subrecipient's inventor discloses invention(s) in writing to Subrecipient's personnel responsible for patent matters. The Subrecipient will submit a final invention report using Federal Awarding Agency specific forms to the PTE's Financial Contact within 60 days of the end of the Project Period to be included as part of the PTE's final invention report to the Federal Awarding Agency.

A negative report is required: Yes

■ Property Inventory Report (only when required by Federal Awarding Agency), specific requirements below.

Additional cost sharing requirements included below:

Additional Technical and Reporting Requirements:

Closeout documents: The closeout documents provided within Attachment 6 must to be completed and returned along with the Final Invoice.

Invoicing Instructions: Invoices shall be e-mailed to subcontract.invoices@umich.edu for processing. In addition to the invoicing terms and conditions identified on the face page of the Subaward each invoice must include the following:

a. PO Number: 3006872268 >> Invoices for costs incurred within the 09/29/2021 - 09/28/2024 Budget Period shall reference this number. A new PO number will be assigned by PTE for each subsequent authorized budget period.
b. A unique invoice number: Each payment request must be identified by a unique invoice number, which can only be used one time regardless of the number of Michigan contracts or orders held by an organization.
c. Invoice period: The period for which the expenditures apply
d. Remittance address
e. Per face page, each invoice must include a certification, signed by an official who is authorized to legally bind the non-Federal entity, which reads as follows: "By signing this report, I certify to the best of my knowledge and belief that the report is true, complete, and accurate, and the expenditures, disbursements and cash receipts are for the purposes and objectives set forth in the terms and conditions of the Federal award. I am aware that any false, fictitious, or fraudulent information, or the omission of any material fact, may subject me to criminal, civil or administrative penalties for fraud, false statements, false claims or otherwise. (U.S. Code Title 18, Section 1001 and Title 31, Sections 3729-3730 and 3801-3812)."

Sufficient detail must be provided to allow for PTE review of invoices. Additional detail or supporting documentation, requested on an as-needed basis, will be made available upon request.

Attachment 5
Statement of Work, Cost Sharing, Indirects & Budget

Subaward Number: SUBK00013926

Statement of Work

( ) Below (•) Attached, 2 pages

If award is FFATA eligible and SOW exceeds 4000 characters, include a *Subrecipient Federal Award Project Description*

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Budget Information

Indirect Information Indirect Cost Rate (IDC) Applied: 81.0 %

Rate Type: Modified Total Direct Costs

Cost Sharing: Yes

If Yes, include Amount: $ 112,383.00

Budget Details

( ) Below (•) Attached, 3 pages

Subrecipient is responsible for making sure that costs incurred/charged are allowable in accordance with the terms and conditions of the Federal award.

Budget Totals

Direct Costs	$ 207,038.00
Indirect Costs	$ 167,701.00
Total Costs	$ 374,738.00

All amounts are in United States Dollars

STATEMENT OF WORK

The City of Ann Arbor will partner with The University of Michigan Transportation Institute (UMTRI) and its partners to accomplish the goals of the ATCMTD Smart Intersections project (SIP). The project will deploy a network of 21 smart intersections along four corridors in Ann Arbor. The project will be executed in nine tasks. The City of Ann Arbor's responsibilities and estimated time commitment for each task are delineated below.

Task 1. Program Management (9 hours)

- Participate in project meetings and coordinate infrastructure task assignments.

Task 2. System Design (92 hours)

- Provide design input on network integration, and smart intersection devices' placement.

Task 3. Preparation of Vehicle Fleets (0 hours)

- City of Ann Arbor does not have assigned tasks in this category.

Task 4. Infrastructure Preparation (879 hours)

- Collect existing asset data.
- Coordinate and deploy necessary changes to existing infrastructure to support the smart intersection project.
- For each of the 21 smart intersections, UMTRI will procure all devices and associated hardware (e.g., POEs) that will not be provided by other project partners.

Task 5. Deployment Testing (525 hours)

- Test smart intersection devices for field installation. Prepare and pre-program devices prior to field installation.

Task 6. Deployment and Analysis (1,331 hours)

- Deploy firewall to accommodate the smart intersection network communication needs.
- Remove existing RSU devices where applicable and install dual mode RSU at project locations.
- Prepare and install smart sensors with edge computing.
- Test transit signal priority, emergency vehicle preemption, dynamic signal optimization with green wave advisory, and vulnerable road user notification.

Task 7. Advanced V2X Technology Living Laboratory (0 hours)

- City of Ann Arbor does not have any additional assigned tasks in this category (tasks completed under Task 6 will equip the intersections that will comprise the living lab with devices and get them deployed on the City's network).

Task 8. Outreach (30 hours)

- Assist project team in outreach.

Task 9. Implementation Plan (78 hours)

- Provide input in the development of implementation guide for infrastructure owner operators.

University of Michigan Transportation Research Institute
to USDOT - Federal Highway Administration for NOFO 693JJ320NF00010
"Advanced Transportation and Congestion Management Technologies Deployment Initiative"

TOTAL FEDERAL BUDGET			Task 1: Program Management		Task 2: Planning		Task 3: Preparation of Vehicle Fleets		Task 4: Infrastructure Preparation		Task 5: Pre-Deployment Testing		Task 6: Deployment and Analysis		Task 7: NR-CV2X Research Hub		Task 8: Outreach		Task 9: Implementation Guide		TOTAL BUDGET 1/1/21 - 12/31/23		
Name*	Project Role	Hourly Rate	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hourly Rate	Hrs	Amount
Braun, K.	Fiber/Communications Tec	Varied	0	0	36	1,341	0	0	240	8,939	120	4,461	400	15,047	0	0	6	226	3	113	Varied	805	30,126
Fischer, D.	Electrician	Varied	0	0	0	0	0	0	40	1,491	18	666	56	2,111	0	0	0	0	3	113	Varied	114	4,381
Fojtik, C.	Supervisor	Varied	0	0	7	340	0	0	48	2,327	40	1,951	48	2,345	0	0	3	148	3	148	Varied	146	7,258
Gurnee, P.	Electrician	Varied	0	0	0	0	0	0	40	1,052	18	470	56	1,490	0	0	0	0	3	80	Varied	114	3,092
Henderson, J.	Electrician	Varied	0	0	0	0	0	0	40	1,052	18	470	56	1,490	0	0	0	0	3	80	Varied	114	3,092
Hogan, S.	Electrician	Varied	0	0	0	0	0	0	40	1,158	18	517	56	1,638	0	0	0	0	3	88	Varied	114	3,401
Longworth, S.	Electrician	Varied	0	0	0	0	0	0	40	1,316	18	588	56	1,863	0	0	0	0	3	100	Varied	114	3,867
Michelson, A.	Electrician	Varied	0	0	0	0	0	0	40	1,158	18	517	56	1,638	0	0	0	0	3	88	Varied	114	3,401
Moreno, M	Electrician	Varied	0	0	0	0	0	0	40	1,246	18	557	56	1,764	0	0	0	0	3	94	Varied	114	3,661
Osborne, J.	Electrician	Varied	0	0	0	0	0	0	40	1,052	18	470	56	1,490	0	0	0	0	3	80	Varied	114	3,092
Sype, J.	Electrician	Varied	0	0	0	0	0	0	40	1,420	18	634	56	2,009	0	0	0	0	3	107	Varied	114	4,170
Tomich, J.	Electrician	Varied	0	0	0	0	0	0	40	1,455	18	650	56	2,060	0	0	0	0	3	110	Varied	114	4,275
VanStone, D.	Electrician	Varied	0	0	0	0	0	0	40	1,187	18	530	56	1,680	0	0	0	0	3	90	Varied	114	3,487
Hess, R.	Transportation Manager	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Hupy, C.	Public Services Area Adm	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Liu, L.	Engineer	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Shewchuk, T.	ITSD Director	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Harris, D.	Network Administration	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Total Salaries			0	0	43	1,681	0	0	728	24,855	358	12,480	1,064	36,624	0	0	9	373	39	1,289		2,205	77,302
Sick/Vacation/Holiday (POOL)		0%		0		0		0		0		0		0		0		0		0			0
Fringes Benefits (Permanent Staff)		67%		0		1,126		0		16,653		8,362		24,538		0		250		863			51,793
FICA (Temps)		0.00%		0		0		0		0		0		0		0		0		0			0
Subtotal Labor				**0**		**2,807**		**0**		**41,508**		**20,842**		**61,162**		**0**		**623**		**2,152**			**129,095**
Equipment																							
				0		0		0		0		0		0		0		0		0			0
Subtotal Equipment				**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**			**0**
Subcontract Partners																							
City of Ann Arbor				0		0		0		0		0		0		0		0		0			0
Continental				0		0		0		0		0		0		0		0		0			0
Ford				0		0		0		0		0		0		0		0		0			0
ISS				0		0		0		0		0		0		0		0		0			0
Iteris				0		0		0		0		0		0		0		0		0			0
P3 Mobility				0		0		0		0		0		0		0		0		0			0
Qualcomm				0		0		0		0		0		0		0		0		0			0
WSP				0		0		0		0		0		0		0		0		0			0
																							0
Subtotal Subcontract Partners				**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**			**0**
Other Direct Costs																							
Aparatus																							
1801	2016 Ingersoll Rand	12.72		0		0		0		509		254		712		0		0		0			1,476
4240	2009 Dodge Caravan	15.76								0		0		0									0
4242	2014 Ford F-150 XL	7.91		0		0		0		506		158		475		0		0		0			1,139
4248	2006 GMC C-1500	7.88								504		158		756									1,418
4271	2016 Ford F-250 4X2	8.78		0		0		0		562		176		527		0		0		0			1,264
4364	Cable Teel Trailer	8.34		0		0		0		0		0		0		0		0		0			0
4405	2001 Reel Trailer	4.80		0		0		0		883		134		653		0		0		0			1,670
4406	2013 Tech Trailer	9.50		0		0		0		228		152		228		0		0		0			608
4410	2007 Triple L Trailer	9.55		0		0		0		0		0		0		0		0		0			0
4417	Felling Equipment Trailer	2.65		0		0		0		0		0		0		0		0		0			0
4505	2013 Dump Truck	15.18		0		0		0		364		243		364		0		0		0			972
4603	2000 Ford F-750	25.95		0		0		0		11,418		4,775		7,266		0		0		0			23,459
4604	2018 Freightliner	23.23		0		0		0		10,221		2,788		5,575		0		0		0			18,584
4612	Platform Truck	10.24		0		0		0		2,785		1,229		1,966		0		0		0			5,980
4616	Bucket Truck	25.82		0		0		0		2,479		1,859		3,718		0		0		0			8,056
4617	2011 Ford F-750	31.55		0		0		0		1,514		1,767		7,951		0		0		0			11,232
4644	Freightliner Digger Derrick	59.31		0		0		0		0		0		0		0		0		0			0
4783	Compact Excavator	14.48		0		0		0		1,274		232		579		0		0		0			2,085
6298	GMC Sierra 4x4	9.21		0		0		0		0		0		0		0		0		0			0
General Supplies				0		0		0		0		0		0		0		0		0			0
Misc Supplies				0		0		0		0		0		0		0		0		0			0
												0											0
				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
																							0
				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
Subtotal Other Direct Costs				**0**		**0**		**0**		**33,249**		**13,924**		**30,770**		**0**		**0**		**0**			**77,943**
Travel																0							
Washington, DC				0		0		0		0		0		0		0		0		0			0
Local Transportation				0		0		0		0		0		0		0		0		0			0
Conference (various locations)				0		0		0		0		0		0		0		0		0			0
Subtotal Travel Costs				**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**			**0**
Total Direct Cost				**0**		**2,807**		**0**		**74,757**		**34,766**		**91,933**		**0**		**623**		**2,152**			**207,038**
Indirect Costs	81.0%			**0**		**2,274**		**0**		**60,553**		**28,160**		**74,466**		**0**		**505**		**1,743**			**167,701**
Estimated Total Cost				**0**		**5,081**		**0**		**135,309**		**62,926**		**166,398**		**0**		**1,128**		**3,895**			**374,738**
Cost Share Amount				**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**			**0**
TOTAL PROJECT COSTS				***0***		***5,081***		***0***		***135,309***		***62,926***		***166,398***		***0***		***1,128***		***3,895***			***374,738***

Double check >> 374,738

University of Michigan Transportation Research Institute
to USDOT - Federal Highway Administration for NOFO 693JJ320NF00010
"Advanced Transportation and Congestion Management Technologies Deployment Initiative"

TOTAL COST SHARE BUDGET			Task 1: Program Management		Task 2: Planning		Task 3: Preparation of Vehicle Fleets		Task 4: Infrastructure Preparation		Task 5: Pre-Deployment Testing		Task 6: Deployment and Analysis		Task 7: NR-CV2X Research Hub		Task 8: Outreach		Task 9: Implementation Plan		TOTAL BUDGET 1/1/21 - 12/31/23		
Name*	Project Role	Hourly Rate	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hrs	Amt	Hourly Rate	Hrs	Amount
Braun, K.	Fiber/Communications Tec	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Fischer, D.	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Fojtik, C.	Supervisor	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Gurnee, P.	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Henderson, J.	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Hogan, S.	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Longworth, S.	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Michelson, A.	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Moreno, M	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Osborne, J.	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Sype, J.	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Tomich, J.	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
VanStone, D.	Electrician	Varied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Varied	0	0
Hess, R.	Transportation Manager	Varied	3	148	4	195	0	0	7	340	4	195	8	391	0	0	6	295	6	295	Varied	38	1,859
Hupy, C.	Public Services Area Admi	Varied	3	219	3	219	0	0	4	290	3	219	3	219	0	0	6	438	3	219	Varied	25	1,822
Liu, L.	Engineer	Varied	3	140	14	643	0	0	44	2,009	36	1,664	88	4,127	0	0	3	140	10	468	Varied	198	9,190
Shewchuk, T.	ITSD Director	Varied	0	0	8	554	0	0	24	2,470	36	2,494	24	1,674	0	0	3	209	10	702	Varied	117	8,102
Harris, D.	Network Administration	Varied	0	0	20	983	0	0	60	2,958	88	4,381	144	7,228	0	0	3	151	10	505	Varied	325	16,205
Total Salaries			9	506	49	2,594	0	0	151	8,066	167	8,954	267	13,638	0	0	21	1,232	39	2,189		703	37,180
Sick/Vacation/Holiday (POOL)		0%		0		0		0		0		0		0		0		0		0			0
Fringes Benefits (Permanent Staff)		67%		339		1,738		0		5,404		5,999		9,138		0		826		1,466			24,910
FICA (Temps)		0.00%		0		0		0		0		0		0		0		0		0			0
Subtotal Labor				**845**		**4,333**		**0**		**13,471**		**14,952**		**22,776**		**0**		**2,058**		**3,655**			**62,090**
Equipment																							
				0		0		0		0		0		0		0		0		0			0
Subtotal Equipment				**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**			**0**
Subcontract Partners																							
City of Ann Arbor				0		0		0		0		0		0		0		0		0			0
Continental				0		0		0		0		0		0		0		0		0			0
Ford				0		0		0		0		0		0		0		0		0			0
ISS				0		0		0		0		0		0		0		0		0			0
Iteris				0		0		0		0		0		0		0		0		0			0
P3 Mobility				0		0		0		0		0		0		0		0		0			0
Qualcomm				0		0		0		0		0		0		0		0		0			0
WSP				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
Subtotal Subcontract Partners				**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**			**0**
Other Direct Costs																							
Tuition Waiver																							
2 Semesters, 1 GSRA pre-candidate				0		0		0		0		0		0		0		0		0			0
Respondent/Subject Fees																							0
Participant Compensation				0		0		0		0		0		0		0		0		0			0
Research Supplies																							0
Vehicle Insurance				0		0		0		0		0		0		0		0		0			0
Vehicle Fuel and Maintenance				0		0		0		0		0		0		0		0		0			0
RSUs with Wi-Fi				0		0		0		0		0		0		0		0		0			0
NEMA Pole Mounts				0		0		0		0		0		0		0		0		0			0
Vision Detection Pole System				0		0		0		0		0		0		0		0		0			0
Contro ler Cabinet				0		0		0		0		0		0		0		0		0			0
Lock for Controller Cabinet				0		0		0		0		0		0		0		0		0			0
PoE Switch				0		0		0		0		0		0		0		0		0			0
Power Supply				0		0		0		0		0		0		0		0		0			0
Ecom PtP Radios				0		0		0		0		0		0		0		0		0			0
iboot				0		0		0		0		0		0		0		0		0			0
Misc. Pole Mount and Mast Arm Hardware				0		0		0		0		0		0		0		0		0			0
Misc. Cables and Connectors				0		0		0		0		0		0		0		0		0			0
Misc. Research Supplies				0		0		0		0		0		0		0		0		0			0
Misc. Supplies for Subject Vehicle Repairs				0		0		0		0		0		0		0		0		0			0
Turbo Research Storage				0		0		0		0		0		0		0		0		0			0
General Supplies																							0
General Supplies				0		0		0		0		0		0		0		0		0			0
Computers under $5k				0		0		0		0		0		0		0		0		0			0
Marketing Supplies and Materials				0		0		0		0		0		0		0		0		0			0
Fedex/UPS Charges				0		0		0		0		0		0		0		0		0			0
Telephone Expenses																							0
Data Lines - Vehicles				0		0		0		0		0		0		0		0		0			0
Merit Line - Bandwidth (UM to City)				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
				0		0		0		0		0		0		0		0		0			0
Subtotal Other Direct Costs				**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**			**0**
Travel																							
Washington, DC				0		0		0		0		0		0		0		0		0			0
Local Transportation				0		0		0		0		0		0		0		0		0			0
Conference (various locations)				0		0		0		0		0		0		0		0		0			0
Subtotal Travel Costs				**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**			**0**
Total Direct Cost				**845**		**4,333**		**0**		**13,471**		**14,952**		**22,776**		**0**		**2,058**		**3,655**			**62,090**
Indirect Costs	81.0%			**685**		**3,509**		**0**		**10,911**		**12,111**		**18,448**		**0**		**1,667**		**2,960**			**50,293**
Estimated Total Cost				**1,530**		**7,842**		**0**		**24,382**		**27,064**		**41,224**		**0**		**3,725**		**6,615**			**112,383**
Cost Share Amount				**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**			**0**
TOTAL PROJECT COSTS				***1,530***		***7,842***		***0***		***24,382***		***27,064***		***41,224***		***0***		***3,725***		***6,615***			***112,383***

Double check >> 112,383

City of Ann Arbor – Budget Justification

Salaries and Wages -
R. Hess, Transportation Manager and Project Head for the City of Ann Arbor, will oversee all aspects of the project. Mr. Hess will hold meetings, and coordinate with the University of Michigan.

K. Braun, Fiber/Communications Technician, will devote 16% of his effort per year, each year of the project. Mr. Braun will oversee the fiber installations.

C. Fojtik, Supervisor, will devote 4% effort per year, each year of the project. Mr. Fojtik will be responsible for supervising the Electricians effort on the project.

Electricians (10) will devote 2% effort each, per year, each year of the project. These electricians will be essential to installing and maintaining devices on City-owned property.

Fringe benefits are calculated at 67% for permanent staff.

Other Direct Costs-
The use of large equipment will be essential to complete the proposed work. The City of Ann Arbor will use established billable rates for this large equipment. Such equipment includes but is not limited to, Ingersoll Rand, reel trailer, tech trailer, dump truck, bucket truck, digger derrick, compact excavator, platform truck, semi-truck and other various sized vehicles.

Indirect costs are calculated at 81% of the total direct costs.

Attachment 6

Notice of Award (NOA) and any additional documents

◉ The following pages include the NOA and if applicable any additional documentation referenced throughout this Subaward.

○ Not incorporating the NOA or any additional documentation to this Subaward.

1. Award No.
693JJ32150006

2. Effective Date
See No. 17 Below

3. **Assistance Listing No.** 20.200

4. Award To

Regents of the University of Michigan
3003 S. State St
Ann Arbor, MI 48109-1274

DUNS No.: 073133571
TIN No.: 38-6006309

5. Sponsoring Office

U.S. Department of Transportation
Federal Highway Administration
Office of Acquisition & Grants Management
1200 New Jersey Avenue, SE
HCFA-32, Mail Drop E62-204
Washington, DC 20590

6. Period of Performance

36-Months from the Effective Date of Award

7. Total Amount

Federal Share:	$9,950,098.00
Recipient Share:	$9,956,585.00
Total:	**$19,906,683.00**

8. Type of Agreement

Cooperative Agreement

9. Authority

23 U.S.C. 503(c)(4)

10. Procurement Request No.

HOTM210139PR

11. Federal Funds Obligated

$9,950,098.00

12. Submit Payment Requests To

See "Payment" clause in General Terms and Conditions

13. Payment Office

See "Payment" clause in General Terms and Conditions

14. Accounting and Appropriations Data

15X044A060.0000.070N44A600.7001000000.41011.610066
00.0000000000.0000000000.0000000000.0000000000- $9,950,098.00

15. Research Title and/or Description of Project

"Smart Intersections: Paving the Way for a National CAV Deployment"

16. University of Michigan

Brian T. Smith 9/29/2021

Signature Date

Name: Brian T. Smith
Title: Interim Executive Vice President & Chief Financial Officer

17. Federal Highway Administration

DAVID JAMES VILLALOBOS Digitally signed by DAVID JAMES VILLALOBOS Date: 2021.09.29 09:21:55 -04'00'

Signature Date

Title: Agreement Officer

Box 16 Continued:

_N/A_____
Signature
Name:
Title:

TABLE OF CONTENTS

ATTACHMENT(s):

1. Technical Application entitled, “Smart Intersections Project”

[redacted]

SECTION A - AGREEMENT DESCRIPTION

A.1 STATEMENT OF PURPOSE

The Federal Highway Administration (FHWA) enters into this Cooperative Agreement (Agreement) with the University of Michigan (UMTRI) to develop model deployment sites for large scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment. These model deployments are expected to provide benefits in the form of:

- reduced traffic-related fatalities and injuries;
- reduced traffic congestion and improved travel time reliability;
- reduced transportation-related emissions;
- optimized multimodal system performance;
- improved access to transportation alternatives, including for underserved populations;
- public access to real time integrated traffic, transit, and multimodal transportation information to make informed travel decisions;
- cost savings to transportation agencies, businesses, and the traveling public; or
- other benefits to transportation users and the general public.

The purpose of this Agreement is to promote the use of innovative transportation solutions. The deployment of these technologies will provide Congress and the United States Department of Transportation (DOT) with valuable real-life data and feedback to inform future decision making.

A.2 LEGISLATIVE AUTHORITY

Specific statutory authority for conducting this effort is found in 23 U.S.C. §503(c)(4), which authorizes the Secretary of Transportation to "…establish an advanced transportation and congestion management technologies deployment initiative to provide grants to eligible entities to develop model deployment sites for large scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment."

Per 23 U.S.C. §503(c)(4)(I)(i), funding for this effort is available from amounts authorized under §6002(a)(1), §6002(a)(2), and §6002(a)(4) of Public Law 114-94, the Fixing America's Surface Transportation (FAST) Act.

The authority to enter into a cooperative agreement for this effort is found under 23 U.S.C. §502 - Surface Transportation Research, Development, and Technology, paragraph (b)(3) which states:

> "(3) **cooperation, grants, and contracts. —** The Secretary may carry out research, development, and technology transfer activities related to transportation—
>
> **(A)** independently;
>
> **(B)** in cooperation with other Federal departments, agencies, and instrumentalities and Federal laboratories; or
>
> **(C)** by making grants to, or entering into contracts and cooperative agreements with one or more of the following: the National Academy of Sciences, the American Association of

State Highway and Transportation Officials, any Federal laboratory, Federal agency, State agency, authority, association, institution, for-profit or nonprofit corporation, organization, foreign country, or any other person."

Per 23 U.S.C. §503(c)(4)(J), the Federal share of the cost of a project for which a grant is awarded under this subsection shall not exceed 50 percent of the cost of the project.

A.3 BACKGROUND

States and jurisdictions across the country are tackling transportation challenges that often result in congestion and unreliable travel for people and goods, negative impacts on the environment, and reduced safety for users and vehicles. According to the Texas A&M University Transportation Institute, Americans spend on average over 40 hours per person stuck in traffic each year for an annual financial cost of $121 billion. Research indicates that cities account for 67% of all greenhouse gases (GHGs) released into the atmosphere, and the transportation sector is the second-biggest source of GHG emissions, responsible for emitting 28% of GHGs into the atmosphere. There were 32,675 deaths and more than 2.3 million injuries from vehicle crashes in 2014, and there were more than 6.1 million reported motor vehicle crashes. Recognizing that implementing technology solutions can help address transportation safety, mobility, and air quality challenges, section 6004 of the FAST Act establishes the advanced transportation and congestion management technologies deployment initiative.

Projects funded under this initiative will deploy advanced transportation and congestion management technologies, including:

i. **Advanced traveler information systems** – Systems that provide real time, predicted, and individualized information about travel choices, based on data from sensors (traffic, weather), mobile sources (personal portable devices, connected vehicles), and other information systems (public transportation, shared-use mobility, traffic incident management, construction, parking, congestion pricing/tolls or other costs) to allow travelers and shippers to make informed decisions regarding destinations, when to travel, routes, or modes. This information should be publicly accessible and not limited to users with smart phones.
ii. **Advanced transportation management technologies** – Technologies that assist transportation system operators in managing and controlling the performance of their systems to provide optimal services or respond to dynamic conditions, including interjurisdictional and intermodal coordination; technologies may include traffic signal equipment, advanced data collection and processing (from sensors, connected vehicles and other mobile sources, other information systems), dynamic lane controls/configurations, and cooperative transportation management algorithms including pricing strategies across jurisdictions/agencies/facilities/modes.
iii. **Infrastructure maintenance, monitoring, and condition assessment** – Technologies and systems that monitor the behavior or assess the condition of transportation infrastructure to allow agencies to better manage their transportation assets through optimizing resource allocation, preventative maintenance processes, and responses to critical conditions.
iv. **Advanced public transportation systems** – Technologies that assist public transportation system operators or other shared mobility entities in managing and optimizing the provision of public transportation and mobility services; technologies may include remote fleet monitoring systems, coordinated communication systems, algorithms, and applications to enable better transit connections for users, advanced data collection and processing (from sensors,

mobile/connected sources, other information systems) to provide dynamic responsive transit services, and communication and data systems that enable shared mobility services.

v. **Transportation system performance data collection, analysis, and dissemination systems** – Technologies and systems that actively monitor the performance of and interactions between transportation systems and permit agencies and other interested entities to conduct analyses and research, and explore innovative, value-added products and services.

vi. **Advanced safety systems, including vehicle-to-vehicle and vehicle-to-infrastructure communications, technologies associated with autonomous vehicles, and other collision avoidance technologies, including systems using cellular technology** – Deployment of technology-based safety systems such as described at Safer Car or at the Intelligent Transportation Systems (ITS) Program, or other applicable safety technologies.

vii. **Integration of intelligent transportation systems with the Smart Grid and other energy distribution and charging systems** – Technologies that link information from ITS and other transportation systems with information from Smart Grid and other energy distribution and charging systems to provide users with better information related to opportunities for recharging electric vehicles, and to provide energy distribution agencies with better information related to potential transportation-user demand.

viii. **Electronic pricing and payment systems** – Technologies that permit users to electronically conduct financial transactions for mobility services across jurisdictions and agencies, such as unified fare collection, payment, and tolling systems across transportation modes; or

ix. **Advanced mobility and access technologies, such as dynamic ridesharing and information systems to support human services for elderly and disabled individuals** – Technologies and systems that leverage data and communications systems to allow public agencies and human service organizations to provide improved mobility services to at-risk users such as elderly, disabled, or other individuals that require transportation assistance.

Advanced technologies can also help to revitalize neighborhoods and regions by attracting more business or residential developments to bring opportunities closer to where people live. Technologies also help provide transportation options and improved multimodal transportation systems, allowing users to have access to safe, reliable, and affordable connections to employment, education, healthcare, goods delivery, and other services. As such, technology helps create pathways to jobs and economic opportunity for traditionally disadvantaged populations.

ITS are laying the groundwork for innovative transportation solutions, with many locations currently serving as laboratories for new types of transportation services. Integrating ITS, connected vehicle technologies, automated vehicles, and other advanced technologies within the context of a jurisdiction or region provides enhanced travel experiences and makes moving people and goods safer, more efficient, and more secure. By enhancing the effective management and operation of the transportation system, these solutions can leverage existing infrastructure investments, enhance mobility, sustainability, and livability for citizens and businesses, and greatly increase the attractiveness and competitiveness of jurisdictions and regions.

A.4 VISION, GOALS, AND FOCUS AREAS

The DOT recognizes that each location has unique attributes, and each location's proposed deployment will be tailored to their vision and goals. Applications may be submitted for deploying any eligible technology. However, this section provides a framework for applicants to consider in the development of a proposed deployment by presenting the DOT's vision, goals, and focus areas.

The DOT's vision for the ATCMTD initiative is the deployment of advanced technologies and related strategies to address issues and challenges in safety, mobility, sustainability, economic vitality, and air quality that are confronted by transportation systems owners and operators. The advanced technologies are integrated into the routine functions of the location or jurisdiction and play a critical role in helping agencies and the public address their challenges. Management systems within transportation and across other sectors (e.g., human services, energy, and logistics) share information and data to communicate between agencies and with the public. These management systems provide benefits by maximizing efficiencies based on the intelligent management of assets and the sharing of information using integrated technology solutions. The advanced technology solutions and the lessons learned from their deployment are used in other locations, scaled in scope and size, to increase successful deployments and provide widespread benefits to the public and agencies

Goals for the advanced transportation and congestion management technologies deployment initiative include:

- Reduced costs and improved return on investments, including through the enhanced use of existing transportation capacity;
- Delivery of environmental benefits that alleviate congestion and streamline traffic flow;
- Measurement and improvement of the operational performance of the applicable transportation networks;
- Reduction in the number and severity of traffic crashes and an increase in driver, passenger, and pedestrian safety;
- Collection, dissemination, and use of real time transportation related information to improve mobility, reduce congestion, and provide for more efficient and accessible transportation, including access to safe, reliable, and affordable connections to employment, education, healthcare, freight facilities, and other services;
- Monitoring transportation assets to improve infrastructure management, reduce maintenance costs, prioritize investment decisions, and ensure a state of good repair;
- Delivery of economic benefits by reducing delays, improving system performance and throughput, and providing for the efficient and reliable movement of people, goods, and services;
- Accelerated deployment of vehicle-to-vehicle, vehicle-to-infrastructure, and automated vehicle applications, and autonomous vehicles and other advanced technologies;
- Integration of advanced technologies into transportation system management and operations;
- Demonstration, quantification, and evaluation of the impact of these advanced technologies, strategies, and applications towards improved safety, efficiency, and sustainable movement of people and goods; and
- Reproducibility of successful systems and services for technology and knowledge transfer to other locations facing similar challenges.

A.5 STATEMENT OF WORK

The Recipient shall execute their proposed work plan as detailed in Attachment 1.

A.6 DELIVERABLES

The Recipient shall provide the deliverables detailed in Attachment 1 and the following items:

*Award date is shown on page 1, Block 17, FHWA signature date.
** FHWA may agree to modify due dates, upon the reasonable request of UMTRI.

Deliverable	Approximate Due Date	Section 508 Compliant?
Kick-off Meeting Conduct a kick-off meeting with DOT at a mutually-agreed-upon location.	Within 4 weeks after agreement execution	No
Quarterly Progress Reports Submit progress reports to document activities performed, anticipated activities, and any changes to schedule or anticipated issues.	Quarterly in accordance with Section C.5.B	No
Project Management Plan The Recipient shall submit to FHWA's Agreement Officer's Representative (AOR) for approval a Project Management Plan, which shall include, at a minimum: a) A **Statement of Work**, with a description of **Tasks and Sub-Tasks** by which the project work activities will be organized, executed, and monitored; b) A **Project Schedule** (Gantt Chart or equivalent) displaying begin and end times for each Task and Sub-Task, plus achievement of Project Milestones; c) A description of major **Project Milestones**, including key Reports, start of operations of important systems or subsystems, and other important deliverables or events; d) A **Risk Management Plan,** which includes: identification and assessment and of all known risks, assignment of risk roles and responsibilities, processes for monitoring and controlling risks, and a risk registry; e) A **Staffing** Table, which identifies a single Project Manager, plus project staff and/or consultants that will lead and support each Task (or Sub-Task if appropriate); and f) A **Project Budget**, displaying planned expenditures for each Task, with a further breakdown by Cost Element for each Task, and by the federal share vs. non-federal share.	Within 60 days after agreement execution	No

Project Evaluation Plan The Recipient shall submit to FHWA's AOR for approval, an Evaluation Plan, which shall include, at a minimum: i. Statement of **Project Objectives**; ii. List of **Evaluation Criteria** (e.g. quantitative performance metrics and/or qualitative assessments) tailored to the Project Objectives; iii. Description of **data-collection** procedures tailored to these criteria, which could include, for example, before/after data, surveys, interviews, system-monitoring data, or other data needed to report on achievement of project objectives; and iv. Outline of **Evaluation Report** (1-page, draft list of topics to be addressed).	Within 120 days after agreement execution	No
Data Management Plan (DMP) The Recipient shall submit to FHWA for approval a DMP that provides a preliminary overview of data that may be collected or created through the project, which shall include, at a minimum: **a) Data description** **b) Data access policies** **c) Data storage and retention approach** The Recipient shall then update the DMP throughout the project with more details on the data that is collected or created, including information on **data rights and standards**. Additional information on DMPs can be found at: https://ntl.bts.gov/ntl/public-access/creating-data-management-plans-extramural-research.	Within 90 days after the agreement execution, to be updated throughout the project.	No
Systems Engineering Documents In accordance with 23 CFR 940.11, the Recipient shall submit electronic copies of the milestone Systems Engineering documents applicable to each component of this project, for approval by FHWA's AOR. For all ITS elements funded by the Grant, this shall include, at a minimum: a) Systems Engineering Review Form (SERF); b) Concept of Operations (ConOps); c) Systems Engineering Management Plan (SEMP); d) Other SE documents as deemed necessary by FHWA; e) System Verification Plan; f) System Validation Plan; and g) Results of the system verification and system validation Plans. FHWA approval will be required for the Concept of Operations and the System Engineering Management Plan. Results of the System Verification and System Validation Plans are to be provided to FHWA to verify such plans were followed and the system components have been properly implemented, but FHWA approval of those documents is not required.	As applicable	No

Annual Budget Review and Program Plan Reporting Submit the Annual Budget Review and Program Plan Report. The report should describe: (1) Overview and schedule of tasks, activities, milestones and deliverables for the upcoming year, to include: • the latest deliverables table or project management schedule; and • a discussion of whether the current approved Technical Application attached to the award needs to be updated or not. If an update is warranted, propose the updates. (2) Overview and forecast budget for the upcoming year, including: • a discussion of whether the current approved Budget Application attached to the award needs to be updated or not. If an update is warranted, propose the updates.	60 days prior to the anniversary date of agreement execution, in accordance with C.5.C	No
Report to the Secretary Submit a report to the Secretary that describes: a. Deployment and operational costs of the project compared to the benefits and savings the project provides; and b. How the project has met the original expectations projected in the deployment plan submitted with the application, such as: 1. data on how the project has helped reduce traffic crashes, congestion, costs, and other benefits of the deployed systems; 2. data on the effect of measuring and improving transportation system performance through the deployment of advanced technologies; 3. the effectiveness of providing real time integrated traffic, transit, and multimodal transportation information to the public to make informed travel decisions; and 4. lessons learned and recommendations for future deployment strategies to optimize transportation efficiency and multimodal system performance.	Annually, beginning one year after agreement execution	Yes
Final Report The Recipient shall provide a final report within 90 days after the termination or expiration of this Agreement. The FHWA AOR in consultation with the Recipient, will determine the final design and scope of the evaluation and report. Submit an electronic copy of all reports to the ATCMTD mailbox at ATCMTD@dot.gov, and to Ryan.Buck@dot.gov Dave.Harris@dot.gov & Thomas.Fisher1@dot.gov	Within 90 days after the termination or expiration of this Agreement	No

Note: Section 508 requirements are included in the Agreement General Terms and Conditions available online at: https://www.fhwa.dot.gov/cfo/contractor_recip/gtandc_generaltermsconditions.cfm

SECTION B – AWARD INFORMATION

B.1 TYPE OF AWARD

This award is a cost reimbursement Cooperative Agreement.

B.2 AVAILABLE FUNDING

The total amount of Federal funding that may be provided under this Agreement is identified on Page 1 of this Agreement in Item No. 7, for the entire period of performance, subject to the limitations shown below:

a. Currently, Federal funds identified on Page 1 of this Agreement, Item Nos. 11 and 14, are obligated to this Agreement. This Agreement is fully funded.
b. The FHWA's liability to make payments to the Recipient is limited to those funds obligated under this Agreement.
c. Costs associated with contingency estimates require prior written approval from FHWA before they are eligible for reimbursement.

B.3 COST SHARING OR MATCHING

Cost sharing or matching is required, with the maximum Federal share being 50%; therefore, a minimum non-federal cost share of 50% is required. The Recipient's cost share value is stated in Item No. 7 on Page 1 of this cooperative agreement. Cost sharing or matching means the portion of project costs not paid by Federal funds. For a more complete definition, please see the Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards at 2 CFR Part 200, including section 200.306 on Cost Sharing or matching. Other Federal funds may be leveraged for the deployment but cannot be considered as part of the ATCMTD matching funds, unless otherwise authorized by statute.

The Recipient's match can be met through direct financial support or through "in-kind" services. By the completion date of the Agreement, the Recipient must have met the cost-sharing requirement. All cost share contributions must be submitted with sufficient detail and/or documentation to support the fair market value of the contribution. If additional detail and/or documentation are determined necessary in order to verify the contribution, the Recipient will provide the requested information in a timely fashion.

B.4 PERIOD OF PERFORMANCE

The period of performance for this Agreement is delineated on Page 1 in Item No. 6.

B.5 DEGREE OF FEDERAL INVOLVEMENT

The FHWA anticipates substantial Federal involvement between it and the Recipient during the project. The anticipated Federal involvement will include: technical assistance and guidance to the Recipient; participation in status meetings, including kick off meeting and project reviews; review and comment on draft documents, as appropriate; performance reporting and financial reporting to ensure that the objectives and the terms and conditions of the agreement are met; and monitoring of performance.

SECTION C - AWARD ADMINISTRATION INFORMATION

C.1 FEDERAL AWARD NOTICES

Only the Agreement Officer (AO) can commit the FHWA. The award document, signed by the AO, is the authorizing document. Only the AO can bind the Federal Government to the expenditure of funds.

C.2 GENERAL TERMS AND CONDITIONS

General terms and conditions including payment procedures, compliance requirements for Section 508 of the Rehabilitation Act of 1973 (as amended in 1998), and governing regulations that apply to this Agreement are available online at:

https://www.fhwa.dot.gov/cfo/contractor_recip/gtandc_generaltermsconditions.cfm - Recipient General Terms and Conditions for Assistance awards. Effective date: March 6, 2015.

C.3 STATUTORY AND NATIONAL POLICY REQUIREMENTS

In addition to the FHWA's General Terms and Conditions incorporated by reference in Section C.2, the Recipient is also required to comply with all applicable U.S. Code: Title 23 requirements, Code of Federal Regulations (CFR): Title 23 requirements, and any other applicable statute or regulation.

C.4 ADDITIONAL TERMS AND CONDITIONS

C.4.A PUBLIC ACCESS TO DOCUMENTS

The Recipient agrees that the resulting deliverables/documentation submitted to the FHWA under this Agreement may be posted online for public access and/or shared by FHWA with other interested parties. The FHWA anticipates the documents cited herein may be posted on an FHWA website or another appropriate website.

C.4.B INDIRECT COSTS

Indirect costs are allowable under this Agreement in accordance with the Recipient's Federally Negotiated Indirect Cost Rates as documented in writing and approved by the Recipient's cognizant Government agency. In the absence of such Government-approved indirect rates, the following rates are approved for use under this Agreement as shown below:

*Type**	*Indirect Rate*	*Period*	*Ceiling Rate (%)*	*Base*
Prov	Sick/Vacation/Holiday	Agreement Period of Performance	26%	Direct labor of pool designated full time employees
Prov	Fringe	Agreement Period of Performance	30%	Direct labor of all full-time employees
Prov	Fringe	Agreement Period of Performance	7.65%	Direct labor of students and temporary employees

In the event the Recipient determines the need to adjust the above listed rates, the Recipient will notify the AO of the planned adjustment and provide rationale for such adjustment. In the event such adjustment rates have not been audited by a Federal agency, the adjustment of rates must be pre-approved in writing by the AO.

This Indirect Cost provision does not operate to waive the limitations on Federal funding provided in this document. The Recipient's audited final indirect costs are allowable only insofar as they do not cause the Recipient to exceed the total obligated funding.

C.4.C DATA RIGHTS

The Recipient must make available to the FHWA copies of all work developed in performance with this Agreement, including but not limited to software and data. Data rights under this Agreement shall be in accordance with 2 CFR 200.315, Intangible property.

C.4.D PERSONALLY IDENTIFIABLE INFORMATION (PII)

Personally Identifiable Information (PII), as defined in 2 CFR §200.1, will not be requested unless necessary and only with prior written approval of the AO with concurrence from the AOR. PII is defined as any information about a human being, living or dead, regardless of nationality, that is maintained by an agency and that permits identification of that individual to be reasonably inferred by either direct or indirect means (as in data mining), including, but not limited to, name, social security number, date and place of birth, mother's maiden name, biometric records, education, financial transactions, medical history, non-work telephone numbers, and any other personal information that is linked or linkable to an individual.

C.4.E KEY PERSONNEL

The Recipient must provide notice to the AO of any changes in Key Personnel specified in the award. The notice will provide a Resume of the replacement for such Key Personnel. The following person(s) are/have been identified as Key Personnel:

Table C.4.E -- Key Personnel

Names	Title/Position
Dr. Henry Liu	PI, UMTRI
Dr. James Sayer	Co-PI, UMTRI
Debby Bezzina	Senior Program Manager, UMTRI
Dr. Shailish Patil	Principal Engineer, Qualcomm
Martin Nathanson	Chief Technology Officer, P3 Mobility

C.4.F PROGRAM INCOME

Pursuant to 2 CFR 200.307, Program income earned during the Agreement period must be added to the Federal award and used for the purposes and under the conditions of the Federal award, unless otherwise approved by the AO. Program income must not be used to offset the Federal or Recipient contribution to this project.

C.4.G SUBAWARDS AND SUBCONTRACTS

Unless described in the application and funded in the approved award, the Recipient must obtain prior written approval from the AO for the subaward, transfer, or contracting out of any work under this award that exceeds the simplified acquisition threshold established under 2 CFR 200.1. This provision does not apply to the acquisition of supplies, equipment and general support services.

The following subawards and subcontracts are currently approved under this Agreement:

Name
City of Ann Arbor
Continental
Iteris
Econolite
P3 Mobility
Purdue University
WSP

Approval of additional subawards or subcontracts under the agreement is contingent upon the Recipient providing a fair and reasonable cost/price determination, as well as documentation supporting obtaining the required services under those subawards by non-competitive means, if applicable. Consent to enter into additional subawards or subcontracts will be issued through a formal amendment to the Agreement, or by written notification from the AO. Consent is currently withheld under this Agreement for the following subawards/subcontracts:

- None

C.4.H ORDER OF PRECEDENCE

The Recipient's technical and budget applications are accepted, approved, and incorporated herein as Attachment 1 and Attachment 2. In the event of any conflict between this Agreement document and the Recipient's application, this Agreement document shall prevail.

C.4.I DESIGNATION AS RESEARCH OR NON-RESEARCH AGREEMENT

This Agreement is designated as: *RESEARCH AND DEVELOPMENT*

C.4.J CONFERENCE SUPPORT RESTRICTIONS

The Recipient must obtain written approval from the AOR prior to incurring any costs for conference or meeting support. See the definition of conference as contained in 2 CFR 200.432.

Food and beverage costs are not allowable conference/meeting expenses for reimbursement under this Agreement.

NOTE: Costs of meals are allowable as a travel per diem expense for individuals on travel status and pursuant to the Travel clause of this Agreement.

C.4.K TRAVEL

Travel costs are allowable in accordance with 2 CFR §200.475 - Travel Costs.

C.4.L AGREEMENT PERFORMANCE REQUIREMENTS SUMMARY

Not Applicable.

C.4.M DISPUTES

The parties to this Agreement will communicate with one another in good faith and in a timely and cooperative manner when raising issues under this provision. Any dispute, which for the purposes of this provision includes any disagreement or claim, between the FHWA and the Recipient concerning questions of fact or law arising from or in connection with this Agreement and whether or not involving alleged breach of this Agreement, may be raised only under this Disputes provision.

Whenever a dispute arises, the parties will attempt to resolve the issues involved by discussion and mutual agreement as soon as practical. In no event will a dispute which arose more than three months prior to the notification made under the following paragraph of this provision constitute the basis for relief under this article unless FHWA waives this requirement.

Failing resolution by mutual agreement, the aggrieved party will document the dispute by notifying the other party in writing of the relevant facts, identify unresolved issues and specify the clarification or remedy sought. Within five working days after providing written notice to the other party, the aggrieved party may, in writing, request a decision from one level above the AO. The AO will conduct a review of the matters in dispute and render a decision in writing within 30 calendar days of receipt of such written

request. Any decision of the AO is final and binding unless a party, within thirty (30) calendar days from the date of the AO's written decision, requests further review as provided below.

Upon written request to the FHWA Chief Acquisition Officer or designee, made within 30 calendar days after the AO's written decision or upon unavailability of a decision within the stated time frame under the preceding paragraph, the dispute will be further reviewed. This review will be conducted by the Director, Office of Acquisition and Grants Management. Following the review, the Director, Office of Acquisition and Grants Management, will resolve the issues and notify the parties in writing. Such resolution is not subject to further administrative review and to the extent permitted by law, will be administratively final and binding. Nothing in this Agreement is intended to prevent the parties from pursuing disputes in a United States Federal Court of competent jurisdiction.

C.5 REPORTING

C.5.A ADDRESS FOR SUBMITTAL OF REPORTS AND DOCUMENTS

The Recipient must submit all required reports and documents electronically, under transmittal letter referencing the Agreement number, to the following address(s) follows:

- **Ryan Buck,** Agreement Specialist at the following email address: **Ryan.Buck@dot.gov**
- **Dave Harris,** ATCMTD Program Manager at the following email address: **Dave.Harris@dot.gov**
- **Tom Fisher** Agreement Officer's Representative at the following email address: **Thomas.Fisher1@dot.gov**
- **ATCMTD Inbox, ATCMTD@dot.gov**

C.5.B QUARTERLY PROGRESS REPORT

The Recipient must submit an electronic copy of the SF-PPR (Performance Progress Reports) to the FHWA staff identified under clause C.5.A on or before the 30th of the month following the calendar quarter being reported. Final PPRs are due 90 days after the end of the Agreement period of performance. The SF-PPR is available online at this link.

Table C.5.B -- Quarterly Progress Report Periods

Calendar quarters are defined as:	Reports due on or before:
1st: January – March	April 30th
2nd: April – June	July 30th
3rd: July – September	October 30th
4th: October – December	January 30th

The quarterly progress report must include the required certification pursuant to 2 CFR 200.415, the SF-PPR cover page and the SF-PPR Block 10 Performance Narrative. The Recipient shall complete the Quarterly Reporting Template, expanding on SF PPR Block 10 as necessary, to include the following information:

a. Work performed for the current quarter;
b. Work planned for the upcoming quarter;
c. Status of all planned procurement activities, proposed procurement schedules, and a list of key procurement milestone dates;

d. Description of any problem encountered or anticipated that will affect the completion of the work within the time and fiscal constraints as set forth in the Agreement, together with recommended solutions to such problems; or, a statement that no problems were encountered;
e. A tabulation, clearly delineated by Federal share, cost share and total, of the current and cumulative costs expended by cost element (labor, travel, indirect costs, sub-recipient/subcontractor, etc.) by quarter versus budgeted costs;
f. Work performed in support of the FHWA and DOT Strategic Goals (see Section A.4 – Vision, Goals, and Focus Areas);
g. Budget revisions; and
h. To the extent practical, the above items shall be organized and presented to correspond with the Tasks, Schedule and Milestones as described in the Project Management Plan defined in Section A6.

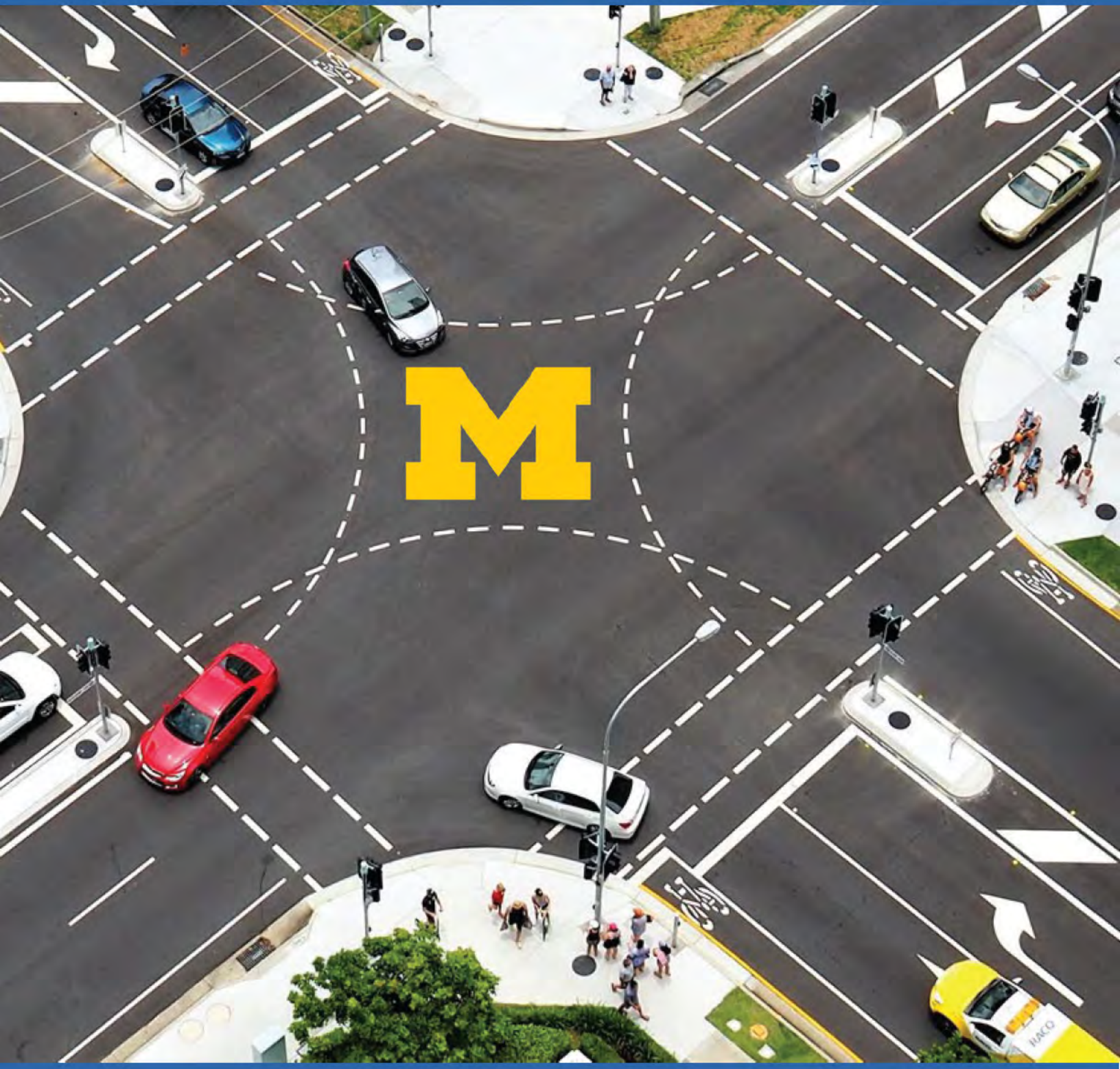
In the SF-PPR Block 11, Other Attachments, include the following information as attached pages:

a. SF-425, Federal Financial Report, and
b. SF-425A, Federal Financial Report Attachment (if applicable).

C.5.C ANNUAL BUDGET REVIEW AND PROGRAM PLAN

The Recipient must submit an electronic copy of the Annual Budget Review and Program Plan to the Agreement Officer 60 days prior to the anniversary date of this Agreement. The Annual Budget Review and Program Plan must provide a detailed schedule of activities, estimate of specific performance objectives, include forecasted expenditures, and schedule of milestones for the upcoming year. If there are no proposed deviations from the Approved Project Budget, the Annual Budget Review must contain a statement stating such. The Recipient must meet via teleconference or web conference with the FHWA to discuss the Annual Budget Review and Program Plan. Work proposed under the Annual Budget Review and Program Plan must not commence until AO's written approval is received.

Smart Intersections: Paving the Way for a National CAV Deployment



Volume I:

Technical Application

I. COVER PAGE

Project Name	**Smart Intersections: Paving the Way for a National CAV Deployment**
Eligible Entity Applying to Receive Federal Funds	**Consortium led by the University of Michigan**
Total Project Cost (all sources)	**$19,906,683**
ATCMTD Request	**$9,950,098**
Are matching funds restricted to a specific project component?	**Yes: sub-recipient in-kind cost share must be allocated to their respective work areas.**
State in which the project is located	**Michigan**
Is the project currently programmed in the: • **Transportation Improvement Program (TIP)** • **Statewide Transportation Improvement Program (STIP)** • **MPO Long Range Transportation Plan** • **State Long Range Transportation Plan**	**NO**
Technologies Proposed to Be Deployed	• **Cellular Vehicle to Everything (C-V2X)** • **Dedicated Short Range Communication (DSRC)** • **Radar sensors (Infrastructure mounted)** • **Camera Detection Systems (infrastructure mounted)**
Is the project located in a rural area?	**NO**
Is the project located in a qualified opportunity zone?	**YES - 4056**

Table of Contents

II. Project Narrative – Smart Intersections: Paving the Way for a National CAV Deployment

1. Introduction

One of the major obstacles that hinders the deployment of connected and automated vehicles (CAVs) is the "chicken and egg" problem, i.e., it is difficult to achieve tangible safety and mobility benefits with low market penetration rate, resulting in few technology adopters because of limited benefits. To overcome this barrier and accelerate the CAV deployment, we propose to deploy smart intersections that can generate pseudo Basic Safety Message (BSM) or Sensor Data Sharing Messages (SDSM) using infrastructure-based object detection sensors and broadcast the proxy BSMs and SDSMs utilizing both cellular vehicle to everything (C-V2X) and dedicated short-range communications (DSRC) technologies. With pseudo BSMs, a number of connected vehicle applications such as red-light violation and intersection movement assist become feasible without high market penetration rate. With SDSMs, the smart intersections will also benefit automated vehicles because it can provide a panoramic view of the intersection such that objects that are beyond the capability of on-board perception sensor can be identified. Therefore, the Smart Intersections Project will accelerate the deployment of connected and automated vehicles (CAVs) by building an infrastructure foundation.

The University of Michigan Transportation Research Institute (UMTRI) has assembled a stellar group of public and private partners to form a consortium for the Smart Intersections Project. The consortium includes UMTRI, Ford, Toyota, Qualcomm, the City of Ann Arbor, Continental, Iteris, WSP, P3Mobility, Econolite, and Purdue University. The consortium offers a one-of-a-kind opportunity to leverage one of the largest operational deployments of connected vehicles and infrastructure in the nation, and in doing so, take significant advantage of previous investments made by the USDOT, the State of Michigan, the University of Michigan, Ford Motor Company, and the City of Ann Arbor.

The Smart Intersections Project addresses the four major obstacles to wide-scale deployment of connected/automated vehicles (CAVs) and infrastructure:

1. How to ensure wide scale benefits of CAV Infrastructure without wide scale adoption;
2. How to generate revenue to facilitate investment needed to build CAV Infrastructure;
3. How to help an inexperienced public entity go from A to Z to build, finance, operate and maintain CAV infrastructure; and
4. How to minimize risk to automobile manufacturers and public agencies by providing a technology-agnostic solution that provides interoperability between dedicated short-range radar (DSRC) and cellular vehicle-to-everything (C-V2X).

We propose a deployment of a network of smart intersections in Ann Arbor, Michigan where vehicles and infrastructure interact in a connected environment using state of the art technology. Our project will accelerate the national deployment of CAVs by building a connected vehicle-

infrastructure foundation that will address the penetration issue. We will also develop an Implementation Guide that includes all the tools a local jurisdiction needs to start down the road of building a self-sustainable CAV eco-system.

This project will enable the City of Ann Arbor to pave the way and be the first of many cities to (1) introduce revenue-generating strategies, which facilitate infrastructure financing costs; (2) improve public safety by reducing vehicle accidents, injuries, and fatalities especially for vulnerable road users, first responders and automated vehicles; and (3) optimize people throughput while decreasing Ann Arbor's carbon footprint.

This project will not only build upon the existing Ann Arbor connected environment, but also on the on-going work on connected intersections by UMTRI/Mcity, CAMP, and the Connected Vehicle Pooled Fund Study to develop a nationally consistent connected intersections for interoperability with production vehicles.

2. Concept of Operations

The concept of operations of the smart intersection is shown in Figure 1.

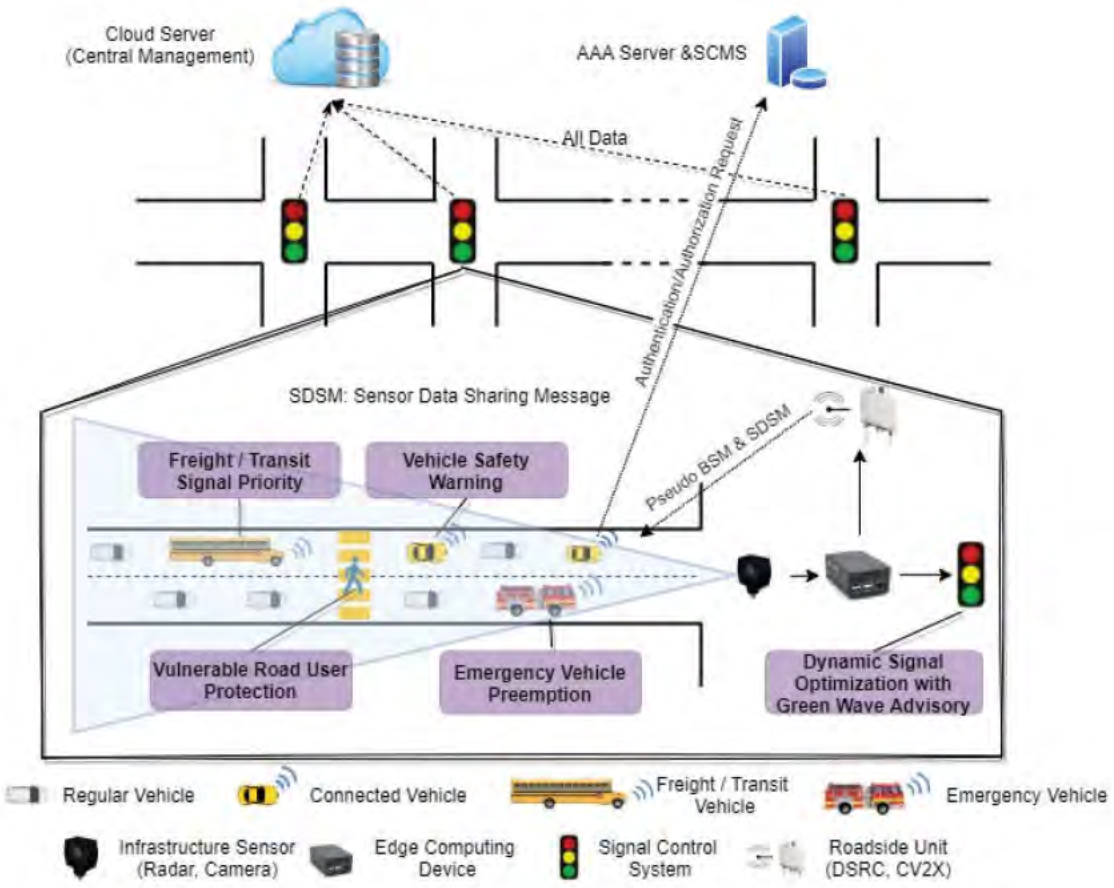


Figure 1: Concept of Operations for the Smart Intersections Project

For each intersection along an arterial corridor, advanced infrastructure sensors including radars and cameras are installed at each approach. The sensors are able to detect and track the status of

road objects within their field of view in real-time. The detection and tracking information is transmitted to an edge-computing device for data fusion and processing. Then the edge-computing device encodes the detected objects into standard SAE messages such as pseudo Basic Safety Message (BSM) or Sensor Data Sharing Messages (SDSM) which are then broadcast through a roadside unit (RSU) over DSRC and/or C-V2X. This creates a connected environment that ensures wide scale benefits even for early adopters of connected vehicle technologies. Supported by the smart intersections, the following five applications will be implemented: Vehicle Safety Warnings[1], Vulnerable Road User Protection, Transit Signal Priority, Emergency Vehicle Preemption, and Dynamic Signal Optimization. As the standard for SDSM (SAE J3224) is being developed, we propose to establish an Advanced V2X Technology Living Lab to investigate the SDSM data quality and demonstrate potential applications with 5G NR based C-V2X. As part of this project, we will also investigate and develop business models that will facilitate the infrastructure investment through public-private-partnership. AAA server technology will be adopted to handle user requests for access to computer resources and to provide authentication, authorization, and accounting (AAA) services. Non-PII (personal identifiable information) will be stored in a cloud server for further analysis with different applications.

3. Implementation of the Smart Intersections Project

To implement the concept of operations, the Smart Intersections Project is broken down into individual, executable elements, which are shown in Figure 2 below and are described in the following sections.

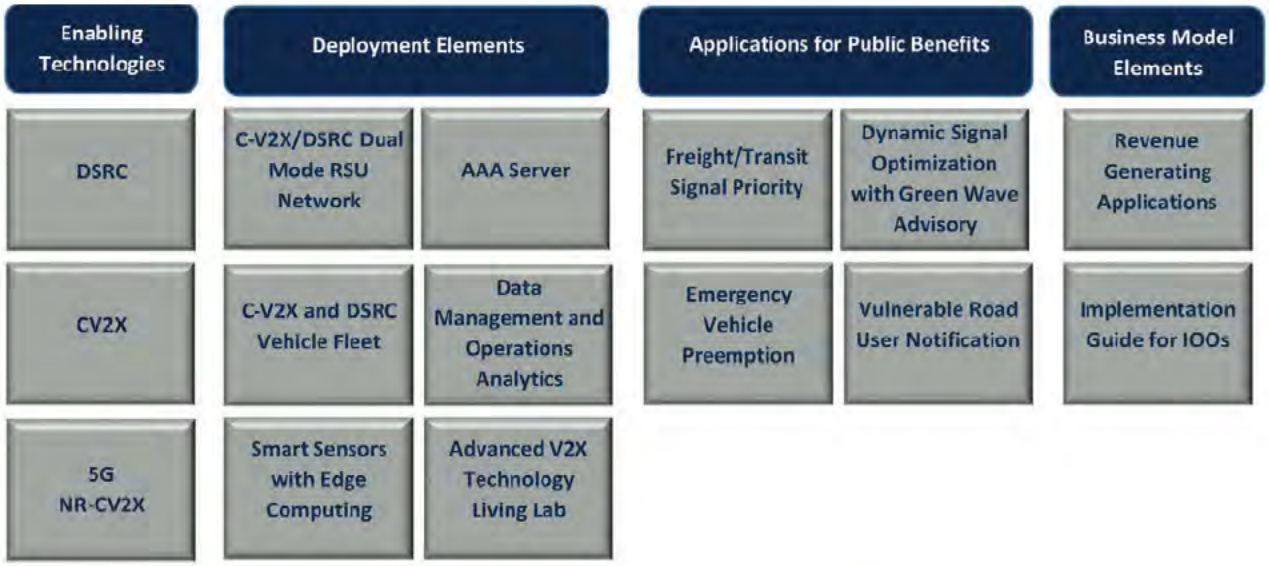


Figure 2: Components of the Smart Intersections Project

[1] Vehicle Safety Warnings include Forward Collision Warning (FCW), Emergency Electronic Brake Light (EEBL), Curve Speed Warning (CSW), Intersection Movement Assist (IMA), Ice Warning, Red Light Violation Warning (RLVW), and Emergency Vehicle Approach (EVA), all of which are currently deployed on the aftermarket safety device (ASD) fleet in Ann Arbor.

3.1. Enabling Technologies

The crux of the Smart Intersections Project is the enabling technologies that will establish the foundation for the deployment.

3.1.1. Dedicated Short-Range Communication (DSRC)

Ann Arbor currently has 75 DSRC roadside units (RSUs) as shown in Figure 3. The RSU network includes 69 production RSUs, which use production security certificates.

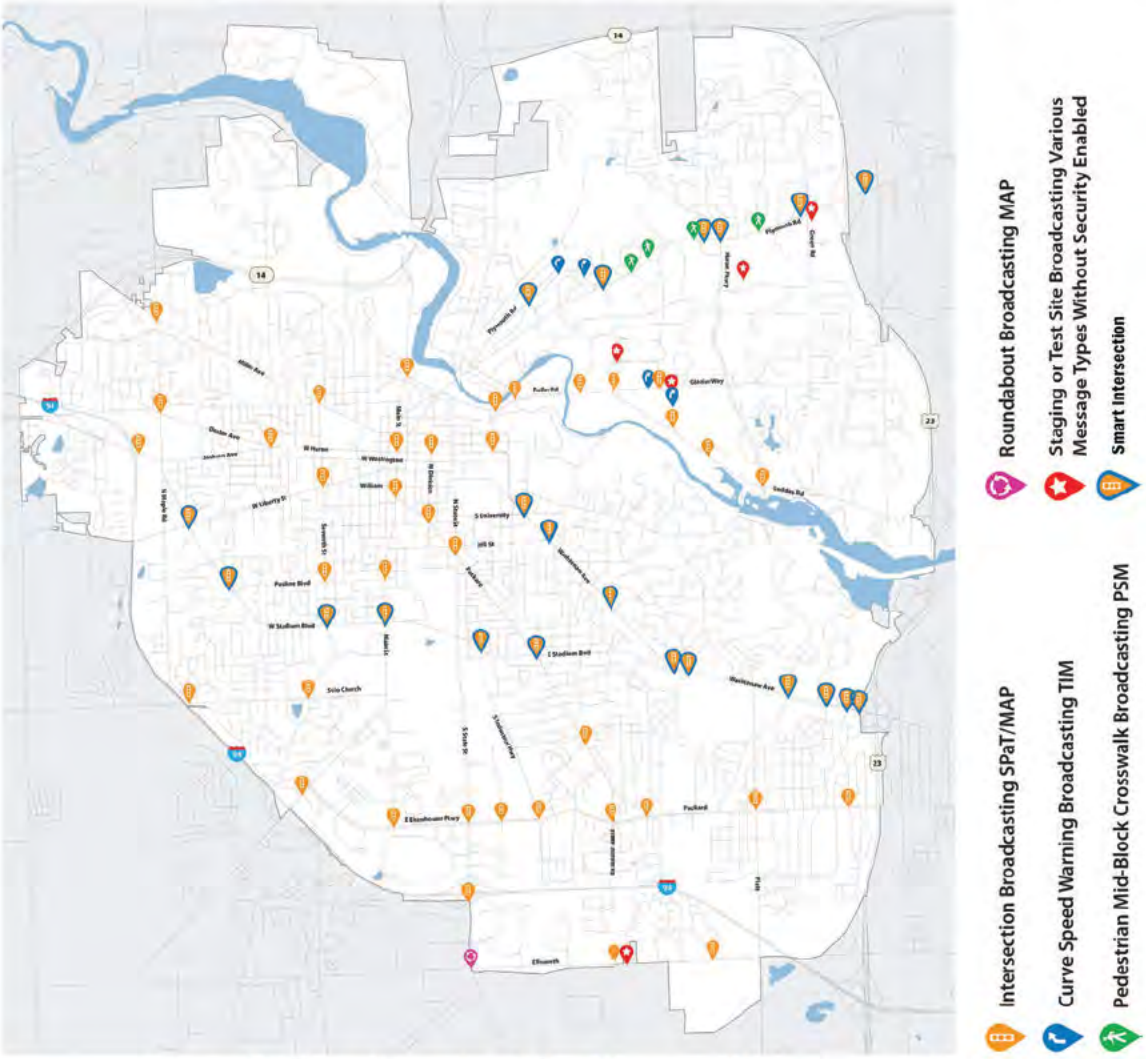


Figure 3: The existing Ann Arbor Connected Infrastructure Deployment

Additionally, there are 6 staging/test sites located at Wheeler (2), UMTRI, Green/Plymouth, Glazier/Fuller, and Bonisteel north of Fuller. The staging sites use test security certificates and are used to verify software and firmware before rolling out to the production sites. The UMTRI site is also used for demonstrations of ice warning and curve speed warning. The UMTRI RSU broadcasts TIMs to allow a safe demonstration of otherwise dangerous scenarios.

There are 2175 DSRC-equipped vehicles currently deployed in Ann Arbor. They are a combination of vehicle awareness devices (VADs) and aftermarket safety devices (ASDs). The

VADs only transmit BSMs; they do not warn the driver. The ASD-equipped vehicles also have a display and speaker that provides warnings to the driver. However, the security certificates on both devices were preloaded and are set to expire beginning in 2021. Because the VADs do not have any over-the-air (OTA) capability, they will be decommissioned beginning in 3Q2020. That will leave a fleet of 1,250 DSRC ASDs for the Smart Intersections Project, which do have OTA capabilities. However, the devices will need to be re-enrolled prior to obtaining new certs OTA.

The status of RSUs and vehicles can be found on the UMTRI website as an interactive tool that is publicly available. It shows vehicle locations and movements – although delayed 5 minutes to ensure the privacy of our participants. The status of the signals and phases are also available by clicking on any of the RSU locations.

The connected vehicle and infrastructure industry has evolved on many fronts since the Ann Arbor deployment was initially set up under the Safety Pilot Model Deployment program (DTFH61-11-C-00040). Because the advanced notice of proposed rulemaking for V2V was never adopted by the new administration, an alternate technology was introduced: C-V2X. This caused much division in the industry, but a dual mode RSU deployment, as in this proposal, is a viable national solution. The DSRC/C-V2X dual mode RSU provides a long-term solution that allows DSRC and C-V2X to operate simultaneously, without interference. It is risky for automobile and device manufacturers to guess what technology will "win." They stand to lose millions of dollars if they back the wrong technology. This has caused delays in launching CV technology by some automobile manufacturers. Any delay means that lives will continue to be lost due to accidents on our roads. However, this solution allows manufacturers to proceed without risk and start saving lives immediately. Either DSRC or C-V2X can provide the desired outcome for the manufacturer – essentially either decision is correct. This is true for agencies and other road operators as well. They don't have to decide on what will win out. Should they equip their streets with DSRC or C-V2X RSUs? The answer is to deploy the DSRC/C-V2X dual mode RSU.

In June 2016, the FCC released a Public Notice seeking additional comment to update and refresh the record on sharing the 5.9 GHz Band. This led to an agreement between the FCC and USDOT to undertake three phases of testing to determine whether spectrum could be safely shared between V2X technologies and unlicensed devices. The first phase of this testing began in October 2016. In fact, UMTRI provided some DSRC units for initial bench testing. Before the testing was completed, in December of 2019, the FCC issued a Notice of Proposed Rulemaking (Docket 19-138) that would reallocate 45 MHz of the safety spectrum to unlicensed users and allocate the remaining 30 MHz to DSRC (10MHz) and C-V2X (20 MHz). Of course, the specific radio technologies used in this project will be guided by any FCC actions. The Smart Intersections Project will provide an excellent foundation to conduct necessary testing. Furthermore, this initial deployment can only be done in a setting where there is a sufficient number of both equipped vehicles and infrastructure, as well as the demonstrated depth of knowledge regarding the necessary steps to successfully deploy connected vehicle technology in a real-world environment. Both of these qualities exist in Ann Arbor with the Smart Intersections Project team.

When the FCC rule making is published in the Federal Register, the University of Michigan team will collaborate with FHWA and other U.S. DOT stakeholders to develop a mutually agreed upon solution to address compliance with the ruling. The Statement of Work will be updated accordingly.

3.1.2. Cellular Vehicle-to-Everything (C-V2X) and 5G New Radio (NR) C-V2X

C-V2X is based on a 3GPP physical layer technology that targets V2X services. The first release of C-V2X services was defined during Release 14 and was completed in early 2017. Additional enhancements were introduced in Release 15. Release 14/15 that were LTE based, targeted basic safety services, and supported V2X applications developed and standardized for years by SAE and others. It was built upon the direct communication (also known as sidelink or PC5) between phones defined during Releases 12 & 13. Releases 14/15 C-V2X has several key technological advantages in terms of range, reliability, and guaranteed latency. The technology has been extensively tested and successfully trialed in many regions of the world and is now moving towards deployment in China and the United States.

5G NR (New Radio) was defined by 3GPP during Release 15. A 5G NR based C-V2X was defined in Release 16. This standard was completed in June 2020. 3GPP continues to evolve the technology during Release 17, which is currently ongoing.

5G NR based C-V2X offers several features and enhancements. More specifically, 5G NR V2X has a substantially better data rates, latency, and reliability. This is enabled by leveraging the advantages of 5G NR framework. Additionally, several key enhancements have been added. These include

- Multicast with distance-based reliability and application relevancy: Multicast communication enables reliable communication by adding HARQ feedback. Adding distance-based reliability allows reliable performance in varying environments.
- Connectionless 'on-the-fly' distance-based groups: The idea here being that the vehicles can form a multicast group with distance-based reliability without exchanging messages to form and break up groups. This allows reliable communication without the overhead of forming and breaking up the group.
- Efficient sidelink link level design for optimized performance at all speeds: This has been achieved by designing a physical layer that is dependent on the speed and has led to substantial gains in the physical layer performance.

Qualcomm has developed a prototype with similar design as R16 5G NR based C-V2X. For this project, we plan to use the prototype to demonstrate sensor data sharing. A demonstration of the prototype is shown here. https://www.qualcomm.com/invention/5g/cellular-v2x

3.2. Deployment Elements

The Smart Intersections Project will bring together many aspects of connected vehicle and infrastructure technology to deploy a cohesive eco-system that can scale up to a national deployment, paving the way for commercialization of CAVs.

3.2.1. C-V2X/DSRC Dual Mode RSU Network

Smart intersection technology will be installed at 21 sites (reference Figure 3). The DSRC RSU currently installed at each of these sites will be replaced with a dual mode C-V2X/DSRC RSU. Radar and vision systems will also be installed at each site. The RSUs will be configured for each site and the MAP message generated from a LIDAR survey of the intersections. The 21 sites will be along three main arterials in Ann Arbor: Plymouth Road, Washtenaw Avenue, and Stadium Boulevard.

The remaining DSRC RSUs currently deployed in Ann Arbor (52 sites), will be maintained.

- 2 CSW Sites (4 RSUs)
- 4 pedestrian mid-block crosswalks
- 39 intersections
- 1 roundabout
- 6 staging/test sites

Additionally, the firewall and router will be upgraded from the current configuration to accommodate the smart intersection network. A map of the deployment area showing the DSRC sites and smart intersections is included in Appendix A (a larger version of Figure 3).

3.2.2. DSRC and C-V2X Fleets

UMTRI will maintain a fleet of 1,150 DSRC vehicles equipped with ASDs currently deployed in Ann Arbor. The fleet consists mainly of personal vehicles owned by lay participants. In addition to this fleet, we will equip and deploy 200 additional vehicles with C-V2X OBUs. In conjunction with equipping and deploying the vehicles, the team will also:

- Convert one of the current DSRC bus fleets to C-V2X (UM-48, AAATA-94, or AAPS-71), or a mix of fleets.
- Recruit and equip a small fleet of freight vehicles.
- Equip a fleet of emergency vehicles. We have been working with the first responders that service Ann Arbor for several months, and will enter into a memorandum of understanding (MOU) with Ann Arbor Police, Ann Arbor Fire, and Huron Valley Ambulance to equip their vehicles. We have used MOUs successfully to equip the three bus fleets above.

Since 2011, UMTRI has equipped and deployed over 6,000 vehicles with DSRC OBUs. We have a proven process in place for installation and configuration management and the technical expertise to assess whether or not any changes to the process need to be made for C-V2X. On top of that, we have dedicated staff to manage human subjects with the knowledge and tools to adhere to all federal guidelines.

3.2.3. Smart Sensors with Edge Computing

The smart intersections will be equipped with object detection and classification sensors. In this project, we propose to deploy radar detection solutions that can detect and type-classify objects within a broad field of view, for each approach at an intersection. This sensor is capable of providing lane-by-lane advance detection up to 1,000 feet from the radar sensor and tracking object trajectories simultaneously. Using these radar sensors to detect vehicles, each vehicle can

be assigned an identity and their trajectories can be extracted. The vehicle trajectory data will be transmitted to a data processing unit, where they will be converted to the SAE J2735 BSM format. We call them pseudo BSMs because they are actually generated by the infrastructure. The pseudo BSMs will be broadcast from the RSUs located at the intersection through DSRC/C-V2X Dual mode RSU. The radar sensors update the list of tracked objected every 50ms. As a result, the data resolution is adequate to generate BSMs at 10 Hz frequency. The pseudo BSM generation concept is depicted in Figure 1. We will investigate whether the pseudo BSMs can be utilized by equipped vehicles for both V2V and V2I safety and mobility applications planned for deployment.

We note that a key advantage of pseudo BSM is that it allows information about vehicles and vulnerable road users (VRU) that are not equipped with the connected vehicle technology to be shared. The RSU will work as a 'proxy' that encodes and transmits the detected yet not connected vehicles' information into a BSM so that any cars with DSRC radios capable of standard SAE 2735 decoding will be able to detect as if these cars are transmitting BSM themselves. Such technology will boost the CV penetration in a certain area, such as around an intersection, and benefit the CVs in the early stage of the V2X communication adoption. This will enable the benefits of deploying connected vehicle technology to be observed much earlier, i.e., without waiting for a large percentage of vehicles to adopt the technology. Like conventional cellular technology deployment, it is sufficient to deploy sensor equipped RSUs at intersections for early adopters to experience the benefits of the technology from day 1.

We plan to install Econolite Radar Solution at up to 21 smart intersections in the City of Ann Arbor, as shown in Figure 3. Additionally, we plan to test several potential radar and other sensing solutions at Mcity prior to making a final decision on what sensor type and supplier to deploy for the Smart Intersections Project. Each intersection will be equipped with at least four sensors, one per approach. The detection system provides real-time stop bar and advance vehicle detection by monitoring vehicles at signalized intersections using forward-fire radar processing techniques. It additionally can detect pedestrians and other roadway users in closer proximity to the sensor. Regardless of the sensing solution, each intersection will require Econolite's next generation connected vehicle co-processor (CVCP 2.0) or equivalent edge computing device. The CVCP 2.0 includes APIs and source code sharing as needed for UMTRI to interface with native radar protocols and other data modeling tools developed by Econolite. This will facilitate object identification and tracking of pedestrians and vehicles throughout the field of view. Econolite will provide technical support and additional engineering services to meet the research needs of this program on a T&M basis.

3.2.4. Authentication, Authorization and accounting (AAA) Server

P3Mobility's Intelligent Transportation Systems (ITS) infrastructure platform is designed to generate revenue through subscription services enabled by a standards-based V2X ecosystem. The core of the platform is the Authentication, Authorization and Accounting (AAA) Server, which manages the subscriptions accounts. This platform allows the public sector to leverage V2X technology for innovative policies such as usage-based insurance (UBI), Traffic Signal Priority for freight vehicles, road pricing ("tolling"), preferential access to dedicated lanes,

preferential licensing of "Mobility as a Service" providers, and so on. The revenue generating applications for this deployment are described in section 3.4.1 below.

For each service offered at a specific infrastructure location, the Roadside Unit (RSU) is configured to announce the service availability. Upon receiving the announcement, any on-board unit (OBU) within range and possessing the appropriate security credentials for the service will forward a request for service through the RSU to the AAA Server[2].

The AAA Server authenticates the OBU based on the security credentials presented in the request. Whereas these credentials are issued by the Security Credential and Management System (SCMS), which protects the anonymity of the vehicles that use them, the P3Mobility platform allows each OBU to identify itself to the AAA Server.

The AAA Server becomes part of the SCMS "chain-of-trust" by obtaining a "component certificate". The public key for this certificate is included in the service announcement broadcast by the RSU, which in turn, enables the OBU to encrypt PII before it is transmitted over the air. This ensures compliance with the SCMS requirements for protection of anonymity, while simultaneously enabling the AAA Server to manage identified subscription accounts and to keep track of the services delivered to individual vehicles.

Many of the revenue-generating services which can be offered in a V2X ecosystem are enabled by applications developed by P3Mobility as "plugin" extensions to the V2I Hub. The V2I Hub is a software platform developed under the auspices of the USDOT ITS Joint Program Office for deployment at signalized intersections and other ITS infrastructure locations. It is intended to facilitate the inter-operability between RSUs and ITS components such as Advanced Traffic Controllers, Dynamic Message Signs, RTCM (differential GPS correction) base stations and so on. It runs on the Ubuntu/Debian version of the Linux Operating System, which can be deployed on an edge-computing platform. Use of the V2I Hub has been strongly recommended in the joint AASHTO/ITS America/ITE webinars conducted in 2018 to assist agencies in responding to the SPaT Challenge. The open-source platform gives an agency or CAV/ITS development entity complete control over debugging or functional enhancements that may prove necessary during development. This eliminates dependence on hardware vendors to implement innovative functionality beyond the scope of the USDOT/FHWA RSU 4.1 specification, thereby removing a critical risk to project deliverables. The V2I Hub consolidates many of the lessons learned in past CV pilot deployments. Its open architecture reflects an emphasis on enabling vendor-agnostic infrastructure plan, and P3Mobility has taken advantage of this to build plugins supporting the revenue-generating applications described in section 3.4.1 below, such as requests for Signal Controller Prioritization.

3.2.5. Data Management and Operations Analytics

Massive amounts of data including connected vehicle messages and video images will be generated during the regular operation of the proposed system. These data are directed to AWS

[2] It should be noted that the incremental bandwidth consumption, due to the handshaking between the OBUs and the AAA server, is negligible.

cloud storage, database services, and UMTRI's private database and storage. The detailed plan to store and manage data is as follows:

Probe Vehicle Data (PVD): Each OBU (On-Board Unit) saves the BSM part 1 and 2 and bundles them up into a PVD. The PVDs are offloaded whenever the vehicle is in the range of an RSU. The RSU will advertise (via WSA) that the function is available, and the OBU will request access to an IPv6 connection. The OBU will use the IPv6 connection to offload the PVDs to a microservice living on AWS Lambda that decodes the raw messages. The decoded data are then pushed into the AWS RDS MySQL database instance. As the database size will grow over time, another regular microservice will be established after three years of deployment, collect records older than three years, and dump it into files and save in AWS Simple Storage Service (S3). Such a method will maintain the database in a stable size of 1TB, considering 100 probe vehicles.

Vehicle-stored PCAPS: The OBU is equipped with an external media device (micro-SD card). The OBU stores all transmitted and received messages in pcap form. These vehicles will return to UMTRI at least once a year. When the vehicle is at UMTRI, the data from the SD card is transferred to the UMTRI private storage. The data is wiped from the SD card and returned to the vehicle for additional data collection. This data contains PII in the form of GPS coordinates.

Video: There are, in total, 38 mid-block pedestrian crosswalks are equipped with a GRIDSmart video system for pedestrian detection. Besides, there are three research intersections with Continental's Intelligent Intersection System (dual-camera system). In total, there are 62 static camera image "snapshots" at an approximate rate of 1Hz. The video will be directed to AWS Simple Storage Service (S3). The first-year data will be stored in S3 One Zone, and then data older than one year only needs to be accessed infrequently, and these data will be moved to S3 Glacier or S3 Glacier Deep Archive. There will be a total of 40TB video data generated per year.

Radar sensor data: At each intersection, four Econolite AccuScan 600 radar sensors are deployed. These sensors will detect, identify, and track vehicles and other road users such as cyclists in the range of 20-50 meters. The information is forwarded to the edge device, and the edge device will transmit this information to AWS RDS MySQL at a 1Hz rate. The radars will generate 1 GB data per intersection per year.

BSM Forward: The RSU will forward BSM part 1 to the UMTRI Traffic Lab servers in near real-time. These files may contain personally identifiable information (PII) if the RSU is adjacent locations that can receive BSMs from a vehicle start or endpoint, such as a house. The BSM forwarding is a service provided by the RSU. The RSU is configured to send the BSMs directly to AWS S3. In the early stage of the deployment, as the CV penetration rate is very low, the data cost from this aspect can be neglected. When fully developed, a busy intersection will forward roughly 5 TB of BSMs per year.

SPaT Forward: The traffic controller can only transmit over IPv4. The controller encodes the SPaT data compliant with the NTCIP standard in the ANS.1 format per SAE J273503. The SPaT data is sent to an aggregation server deployed on AWS Lambda for decoding. The service analyzes the data transmission, adds fields to identify the intersection push to the AWS database. This data does not contain PII. The corresponding MAP messages can be provided if needed but would be provided separately. Since MAP only changes when a physical change occurs to the geometric description of the intersection, it only needs to be provided initially (one per intersection) and then upon change. Users that subscribe to a map service would not need the MAP messages for application development. This task will generate 25GB data per intersection

per year, and the 19 intersections will generate roughly 500GB data per year. The records older than one year will be dumped into a file and moved to AWS S3 Glacier.

A data management plan (DMP) will be developed that describes all data that is planned to be collected, the data format and metadata standards, access policies, policies for re-use, redistribution, and derivatives; and plans for archiving and preservation. The data archive facility shall be a USDOT approved repository. Although not required, we support the Department's goal to make relevant data available to DOT and the public to further advance the objectives of this initiative.

The data collected are planned to be used for:

- Complete benefit-cost analysis for the project and submit a report to the Secretary describing the deployment and operational costs compared to the interests and savings, and how the project has met the original expectations of project in the deployment plan.
- Develop the Implementation Guide – a playbook and set of tools for IOOs to build and generate revenue from CV infrastructure.
- Support application development for public benefits and business models.

3.2.6. Advanced V2X Technology Living Lab

In this project, we propose to establish a living laboratory with two smart intersections and four development vehicles to study the advantages of 5G direct communications and how it can enable newer applications for connected & autonomous vehicles (CAV). As mentioned in section 3.1.2, 5G NR based C-V2X has several new features that enable lower latency, higher reliability, and higher data rate. The living laboratory will use the prototype platform developed by Qualcomm to evaluate newer applications. One of the newer applications being considered is sensor data sharing for autonomous vehicles. Autonomous vehicles require accurate knowledge of road conditions, road obstacles and road users to make safe and efficient driving decisions. While conventional sensors like camera, radar, LIDAR etc. can provide good sensing information, they face challenges in intersections where non-line of sight conditions may not allow observation of road obstacles. Sharing sensed data in such scenarios can be particularly useful and important to ensure that vehicles remain autonomous in such scenarios. This is illustrated in figure 4 below.

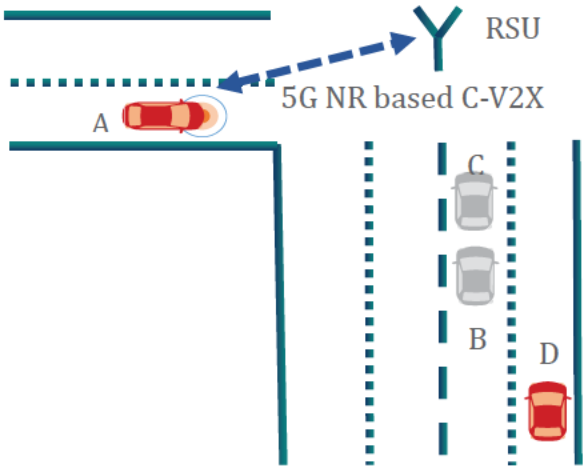


Figure 4: Intersection with a 5G NR Based C-V2X

From roadside object detection sensors, the intersection RSU will sense vehicles that are in the vicinity of the intersection and transmit the information to a vehicle with 5G NR based C-V2X modem. For example, in the RSU informs Vehicle A about Vehicles B, C, and D that it senses. Such an exchange will allow the Vehicle A to learn about the presence of and information about Vehicles B, C, and D without requiring them to be equipped with V2X capability. Knowledge of Vehicles B, C, and D at the Vehicle A will help Vehicle A traverse the intersection potentially in an autonomous manner without an issue.

To address the sensor data sharing issue SAE J3224 is defining Sensor Data Sharing Message (SDSM) and its associated use case. The main idea is to use RSU- and vehicle-mounted sensors to detect real world environment and share information about the same in a common standardized format. Each SDSM provides a compressed description of one or more objects detected by the RSU. The message structure will contain various descriptive fields that will be targeted towards helping autonomous driving. The message will not only contain information about vehicles but also about other entities like pedestrians, bicyclists, road obstacles, etc. For each of the object sensed, the information transmitted will not only include basic information like location and trajectory of the object, but more detailed information, such as: (1) classification of the object such as vehicle, scooters, pedestrian, bicyclists, etc.; (2) location and motion state (speed, heading); (3) bounding box of the detected objected, including the confidence associated the dimensions of the object; and (4) atatus of the detected object such as headlight beams and turn signal status. SAE J3224 is currently in drafting stage and can benefit substantially from the experimentation done as part of the trial deployment. Our industry partners want to understand the quality of the data produced (accuracy, latency, and other minimum performance requirements) to determine what applications can be enabled. We will equip two smart intersections with 5G NR based C-V2X RSUs that can transmit sensor data sharing message (SDSM) to four development vehicles with 5G NR based C-V2X capability. The trial deployment will require an experimental license to use the 5.9GHz spectrum. UMTRI has successfully applied for and received an experimental license for C-V2X testing in 2020. The process for both production and experimental FCC licensing is well understood.

3.3. Applications for Public Benefits

The applications targeted for the Smart Intersections Project will improve safety and increase throughput.

3.3.1. Transit Signal Priority

Traditional transit signal priority (TSP) uses loop detectors or vehicle-based signal emitters to request service in a “check-in/check-out” method. Usually, the first-in-first-out (FIFO) strategy is adopted when multiple transit vehicles arrive at one intersection at the same time from conflicting movements. This may not be the best solution since 1) the FIFO strategy may not be optimal, in terms of total transit vehicle delay; and 2) the delay of regular vehicles are not taken

into consideration. The TSP application may increase the delay of other road users. Moreover, current priority systems can't differentiate types of vehicles, priority levels, vehicle routes and vehicle status. They merely provide the same priority for all transit vehicles at all times.

We propose to implement the Multi-Modal Intelligent Traffic Signal System (MMITSS) system in Ann Arbor's connected vehicle environment. MMITSS was developed through a USDOT Pooled Fund project that aims at developing next generation traffic signal control system serving multi-modal users including general vehicles, transit vehicles, emergency vehicles, and VRUs in a connected vehicle environment. The vision for the MMITSS application is to conduct overarching system optimization that improves the signalized intersection operations by reducing passenger vehicle delay, granting signal priority for multiple priority vehicles (e.g., transit and freight), providing preemption for emergency vehicles, and protecting pedestrian movements on the crosswalk. The MMITSS prototype has been deployed in several locations across the US including Anthem, Arizona, Salt Lake City, Utah, El Camino Real, California, and Tampa, Florida. Recently, a new version of MMITSS source code was releases on Github (https://github.com/mmitss/mmitss-az) which is focused on making the system readily deployable. In the proposed Smart Intersections Project, we plan to implement and improve two of the MMITSS use cases: transit signal priority and dynamic signal optimization.

Through the current AACVTE project, 152 transit buses from two transit agencies are already equipped with onboard communication devices and able to talk to the infrastructure through the DSRC network. In this project, we will install one bus fleet with C-V2X to support the cellular network. In the MMITSS TSP application, when an equipped bus is approaching a smart intersection, the priority request message will be sent to the infrastructure containing much more information than just an arrival notification. Data such as vehicle status (location, speed, acceleration, heading, etc.), estimated time of arrival, requested signal phase, priority level, can all be used by the smart intersection to determine whether and how to grant priority to each transit vehicle. Beside the transit vehicles, the smart intersection is also aware of the trajectories from other vehicles, which can be used to better accommodate the priority requests. For example, if the transit vehicle is approaching a long queue, then the green phase can be granted earlier to allow the queue to be discharged before the arrival of the transit vehicle.

In this project, we will improve the current MMITSS TSP application in two ways. First, the proposed TSP system will be integrated with the dynamic signal optimization application discussed in Section 3.3.3. Combining with current traffic conditions estimated from the trajectory data of other vehicles, a joint traffic control strategy can be developed to provide priority to transit vehicles, while minimizing negative impacts on general traffic. The integrated transit signal priority system will provide more efficient and accurate control based on current traffic conditions. Second, the original MMITSS TSP application is a passive system in which the priority requests are always sent to the infrastructure once the vehicle enters the communication range and priority is always granted. However, priority may not be needed every time for each transit vehicle. In this project, a new module will be developed to determine whether the priority will be granted based on transit operation status and current traffic condition. Some use cases include an early bus with a few passengers may not receive priority, while a full and late bus can; and a priority request that may cause spillover in other approaches may not be granted.

3.3.2. Emergency Vehicle Preemption

First responders refer to the road users that provide emergency services to enhance the quality of life of the general public. According to Bureau of Labor Statistics, 46% of all emergency service provider fatalities were related to motor vehicle crashes during the 2013-2017 period[3], which is a surprisingly high number. Unlike other road users, emergency vehicles (EVs) interact with signalized intersections for the sole purpose of providing emergency services to the public. It is imperative that they receive safe and effective prioritized service at these intersections and roadway sections. EV preemption can greatly reduce the EV delay at signalized intersections. However, prevalent EV preemption methods may increase the risks of EV crashes when multiple EVs are approaching the intersection at the same time, because all preemption requests will be granted without coordination. As a result, how to coordinate other road users and traffic signals to minimize the delay of multiple EVs while maintaining safety is still a challenging problem.

In this project, we will develop and deploy EV preemption with the support from smart intersections. When an EV is approaching a smart intersection, they can be detected in two ways: 1) If the EV is equipped with an OBU, it communicates with the infrastructure and notify its arrival through the priority request messages similar as in the TSP application; 2) if the EV is not equipped, it can still be detected by the advanced infrastructure sensors through object detection. Once the smart intersection detects an EV, the preemption application will be activated. Different from TSP described in the previous section, where the priority is granted conditionally, the preemption will also be granted and phase skipping is allowed to further reduce the EV delay. However, if multiple EVs has conflicting future trajectories, which can be predicted by the smart intersection, warning messages will be sent to first responders to prevent a crash.

Besides EVs, downstream traffic will also be taken into consideration when designing the preemption algorithm, which will try to alleviate queues and congestions before the arrival of the EV and permit the maneuvering of EVs around traffic. Moreover, through V2X communication, the route of the EV can be sent to the smart intersections when the EV enters the corridor. Through proper signal coordination between intersections, a special "green band" for EVs can be generated. This strategy can further reduce EV delays than preemption at isolated intersections, especially when the space between two intersections is close. Finally, we will also investigate the transition process back to normal signal operations under coordination after providing EV preemption. UMTRI has been working with the City of Ann Arbor first responders to implement the EV preemption applications at selected intersections. The Huron Valley Ambulance has reviewed our plan and intends to add 10 more intersections to the preemption list.

3.3.3. Dynamic Signal Optimization with Green Wave Advisory

Many existing dynamic traffic signal control systems rely upon fixed-location infrastructure-based sensors, e.g., loop detectors, to provide inputs to the control mechanisms. For example, in the City of Ann Arbor, the SCOOT (split, cycle and offset optimization technique) traffic control system is currently implemented at multiple arterial corridors, which requires both stop-bar and advanced loop detectors at each intersection. However, installation and maintenance of these detector-based signal systems is costly, and they are prone to frequent detector errors and failures. In the proposed Smart Intersections Project, vehicle trajectory data will be gathered through advanced infrastructure sensors (i.e., radar and camera) and served as data source for signal optimization. The Intelligent Signal Control (I-SIG) application in the MMITSS bundle

[3] Bureau of Labor Statistics [2018]. Census of Fatal Occupational Injuries, 2017

will be applied as the dynamic signal optimization algorithm. The I-SIG application takes trajectory data as input and solves a two-level optimization problem periodically (e.g., every barrier) and generates optimal signal timing plans in terms of total delay or queue length minimization. Based on the frequent optimization process, traffic signals can be adjusted dynamically in response to traffic demand variation.

One critical limitation that prevents I-SIG being implemented in the real world deployment so far is the low CV penetration rate. Simulation studies[4] show that a critical CV penetration rate of 25% is needed to make the application effective. However, in all the current CV deployment sites including the Ann Arbor Connected Environment with about 2,600 CVs, the average CV penetration rate is still very low (around 3%). With the proposed smart intersection concept, the infrastructure is able to detect and track all the vehicles near the intersection in real-time, which essentially creates a 100% CV penetration rate environment. Under higher CV penetration rate, the I-SIG application shows great advantages over traditional actuated signal control. Moreover, different proportions of data can be sampled from the complete dataset to emulate lower penetration rates. A sensitivity analysis can be conducted to investigate the impact of CV penetration rates on the performance of the application.

In this project, we will also extend I-SIG to the corridor level and consider coordination between different intersections. Coordination parameters such as a common cycle length, offsets between intersections will be added to the signal optimization problem as additional constraints. Meanwhile, the green wave speed (from the offset calculation) will be encoded into the SPaT messages and broadcast to the CVs on the road. Through a human-machine-interface (HMI), CV drivers can take the green wave speed as the suggested speed. In this way, not only the mobility performance can be enhanced, the CVs also generates smoother trajectories, improved fuel efficiency, and reduced energy consumption. One challenge in implementing the corridor-level dynamic signal optimization in the City of Ann Arbor is the mid-block pedestrian crossing. To address this challenge, we will dynamically adjust the offsets based on the activation on the crosswalk and the suggested green wave speed.

3.3.4. Vulnerable Road User Notification

The City of Ann Arbor maintains an extensive network of public non-motorized improvements including 81.5 miles of bike lanes, 12.1 miles of sharrows, 58.5 miles of shared-use paths, 110 major mid-block crossings, 27 minor mid-block crossings, 18 Rapid Rectangular Flashing Beacons (RRFB) and 1 HAWK pedestrian crossing signal. Last year, there were 77 accidents involving bicycles, an increase of 63% over 2015, and there were 68 accidents involving pedestrians, an increase of 42% over 2015 - two fatalities occurred at the mid-block crosswalks. Currently, there are four mid-block crosswalks equipped with VRU detection for notification to equipped vehicles. The basic V2P System Architecture is depicted in Figure 5 below.

[4] Feng, Y., Head, K.L., Khoshmagham, S. and Zamanipour, M., 2015. A real-time adaptive signal control in a connected vehicle environment. *Transp. Res. Part C: Emerging Technologies*, *55*, pp.460-473.

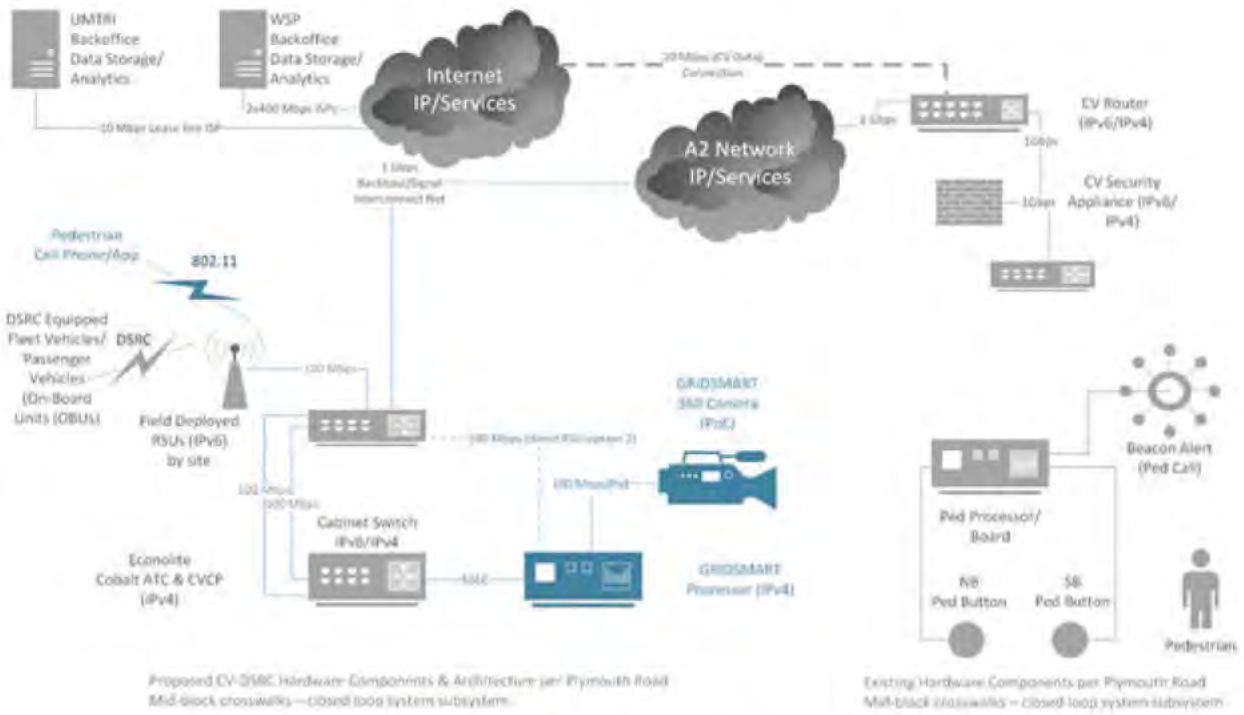


Figure 5: V2P Architecture Diagram

We propose to extend the VRU protection to (1) the 21 smart intersections, utilizing the Iteris camera systems and edge computing that will be installed there; and (2) an additional 20 intersections that have existing GRIDSmart camera systems installed by the City of Ann Arbor, co-located with an existing RSU. The algorithms residing in the CVCP card at the mid-block sites will be ported to both (41 intersections total). UMTRI has also recruited participants and will deploy a smart phone app in the fall of 2020. The smart phone app will transmit the location of the pedestrian to the RSU. When a VRU is detected – either by the camera system or from communications with the smart phone, the RSU will broadcast a pedestrian safety message (PSM). All equipped vehicles (DSRC and C-V2X) will assess the threat and provide a warning to the driver as appropriate. The smart phone app and the camera system also detect bicyclists and other VRUs. The V2P system solution will be compliant with J2735 and J2945/2.

3.4. Business Model Elements

3.4.1. Revenue Generating Applications

Two applications will be deployed to prove out the technology and evaluate the efficacy of revenue generation to offset infrastructure cost.

Freight signal prioritization (FSP). FSP is doubly beneficial in that fleet operators are willing to pay a premium for the same mobility and safety improvements that agencies may want to realize in targeted areas of their jurisdiction. The team will work with an existing DSRC-equipped fleet operator. The OBU will be updated to a C-V2X device that is capable of interfacing with the AAA server. When deployed commercially, the fleet operator will pay a subscription fee and a per-use charge. This project will calculate the potential revenue generated from the fleet.

Equipped-vehicle trajectory awareness (EVTA). We believe that one of the key revenue opportunities for Infrastructure Network Operators lies with the provision of data to insurance companies. Our project will demonstrate one of those data opportunities called Equipped Vehicle Trajectory Awareness (EVTA) and include market research, which evaluates the value of this service to the insurance industry. EVTA will combine vehicle trajectories with concurrent real time traffic signal status in order to capture a level of granularity previously unattainable in conventional telematics-based driver scoring programs. An insurance brokerage partner will be an observer on the project and will present the EVTA data and learnings to an industry group of insurance partners. A market research team will interview these firms in order to collect feedback on data usefulness and product pricing implications.

3.4.2. Implementation Guide for Infrastructure Owner Operators

The process to design, build, operate, finance and maintain connected vehicle infrastructure is a brand new undertaking and involves the co-operation of diverse industries and subject matter experts. P3Mobility has established a team of experts in the fields of public-private partnerships and disruptive technology launch processes that will develop an Implementation Guide for Infrastructure Owner Operators (IOOs) across the U.S. to facilitate the timely rollout of V2X infrastructure. IOOs will need to understand financing, governance, policy making, citizen engagement and technology in order to introduce safety-enhancing, sustainable and commercially viable V2X infrastructure into their jurisdictions. The Implementation Guide will include the following:

Technical Roadmap to rolling out V2X Infrastructure. The infrastructure necessary to establish a comprehensive V2X ecosystem represents a complex configuration of technological components, all of which are subject to on-going changes in technical standards governing their functionality and inter-operability. The technical roadmap will enable the IOO to make procurement decisions for individual components based on vendor-agnostic standards, and to future-proof the inter-operability of evolving V2X applications with ITS components already deployed or envisioned by local transportation agencies. Emphasis will be placed on ensuring that infrastructure deployed in any given jurisdiction can be trusted by all OBUs, regardless of the IEEE 1609.2-compliant certificate management systems in which they are enrolled. This is essential for the ecosystem to support vehicles from other jurisdictions, without which long-term commercially viability cannot be established.

A Guide to Introducing Smart Road Policy Decision (e.g. Pricing and Participation). Smart Road pricing does not have to look the same in every jurisdiction. We are particularly sensitive to the relationship between the economic costs of congestion, as identified in studies commissioned by some of the most important metropolitan transportation agencies in North America[5], and the potential application of road-pricing policy to mitigate these costs. Our technology platform will allow each jurisdiction to implement the pricing policies that are right for their local context. This part of the Implementation Guide will provide model templates reflecting alternative, well-documented approaches to pricing and explain how to use the technology platform to implement each approach.

[5] Work conducted by HDR (https://www hdrinc.com/) for New York (https://www hdrinc.com/portfolio/economic-costs-of-congestion-study), Toronto and Chicago, consistently show that the economic benefits of congestion mitigation runs into the 10's of billions of dollars annually.

Business Case Analysis. The purpose of the business case analysis is to assist an IOO and local jurisdiction with the decision-making on the preferred project delivery method. In order to conduct this analysis, our team would conduct both qualitative and quantitative assessments of various alternative project delivery models—including the expected costs and a high-level risk assessment. The Value for Money (VfM) concept is used to compare P3 and conventional delivery methods for the same investment project. Therefore, VfM in this context answers the question, "Which delivery method provides the 'best deal' for implementing a specific project from the perspective of the government?" The VfM assessment process discussed in this document can be utilized on a case-by-case basis to compare the aggregate benefits and costs of a P3 against those of the conventional alternative. It supports government officials when determining if, when entering into a P3 agreement, they are likely to obtain a better deal compared to conventional procurement for the same project.

The concept of Value for Money (VfM) analysis is evolving in the United States and our Team members are experts in the methodologies used here and around the world. The VfM analysis will allow an IOO to make recommendations on the most appropriate delivery model. We would typically expect to analyze the full spectrum of delivery models, from Design-Bid-Build (DBB) to a full Design-Build-Finance-Operate-Maintain (DBFOM) model. A critical element of the VfM analysis is identification and allocation of risks under differing delivery models. Unlike a conventional delivery, in which most project risks are retained by the public agency, a P3 delivery model allows a public agency to transfer some key project risks to the P3 developer, ideally guided by the principle of placing a risk with the party that is best able to manage that risk at the lowest cost. This section of the Implementation Guide will prepare an IOO to understand the risks, undertake a financial feasibility analysis and work with the local jurisdiction to select the most appropriate delivery model.

Benefit-cost analysis (BCA). A benefit-cost analysis (BCA) establishes whether or not the project is a good use of resources and affordable from the public perspective. Some projects have significant non-financial public benefits, which agencies must weigh against project costs and financial revenues to determine the desirability of the project. Before answering the question that VfM intends to answer of "which delivery method provides the 'best deal' for implementing a specific project from the perspective of the government," BCA answers the question of "whether the project itself is a 'good deal' for society." VfM only considers the financial benefits that accrue to the public agency. BCA can complement VfM analysis to address societal impacts, contribute to transparency and accountability in the P3 procurement process, and potentially open up new revenue streams from the monetization of previously non-financial benefits.

Typically, our first step in developing the BCA is to critically review the existing literature to gather the relevant existing indicators for the effects that are being measured. We then use a "cause-effect tree" to structure the effects that will be included in the methodology and the financial model. Unfortunately, not all effects are reflected in market prices. Yet, where possible, we want to include all relevant and major effects in our methodology and financial model in a credible manner. Therefore, we distinguish the effects in three categories based on how they can be valuated: monetizable effects (unit x market price), quantifiable effect (expressed in a metrics suitable for the effect in question, remain external to the market) and qualitative effects (can be assigned a direction, such as "positive", "negative" or "neutral, but cannot be credibly monetized or quantified, therefore are external to the market).

Our valuation hierarchy is monetization, quantification, and qualitative representation in that particular order. Where possible, we will monetize the effects determined through the aforementioned process, which requires us to identify the credible methods to obtain the market/shadow prices. If an effect cannot be monetized due to a lack of information or a credible methodology, we will scope metrics to be used in the valuation of quantifiable effects. As for effects that can neither be monetized or quantified (i.e. qualitative effects), we will devise a method to represent them in the methodology guidance note and the financial model.

4. The Community's Transportation Needs

Congestion. The City of Ann Arbor is a socially, economically, and culturally diverse community of approximately 117,000 residents, well known for innovation and forward thinking. Encompassing 28.7 square miles, the city includes 296.8 miles of roadway, 81.5 miles of bike lanes and 162 signalized intersections. On weekdays, Ann Arbor experiences an average VMT (vehicles miles travelled) of 2,419,000, predominantly associated with employment as well as visitors – particularly patients to the University's Health System. On seven or more weekends each year, the number of visitors to the city regularly exceeds 100,000 individuals in a single day with people attending special events such as collegiate football games, professional soccer games and art fairs. With the significant daily influx of people working in at the University alone (42,000 employees), as well as that associated with special events, congestion and parking pose persistent significant challenges to the community.

VRU Safety. Ann Arbor, as a university community, also experiences significant pedestrian and bicyclist traffic, along with the associated safety challenges when motorized and non-motorized modes intersect.

First Responder Safety and Response Time. Huron Valley Ambulance (HVA), a nonprofit owned by Emergent Health Partners, provides ambulance service for the Ann Arbor area. HVA operates roughly 53 ambulanced operating in Washtenaw County at any given time. The national standard for arrival of a unit with first responder or higher level capability at an emergency medical incident in 4 minutes or less, 90% of the time. HVA's average response time to life-threatening emergencies is seven minutes.

5. Metrics

The proposed project will be evaluated through a number of different metrics as described below.

Mobility:

- Reduction of intersection delay by 10%. This will be evaluated through a before/after analysis along the smart intersection corridors. Intersection delay and other traffic performance measures will be monitored throughout the project duration. The traffic performance measures will also be shown in real time through Econolite Centracs Signal Performance Software.
- 10% improvement in emergency response time by enabling emergency vehicle preemption. We will conduct a comprehensive before/after study of emergency response times along the smart intersection corridors.

Safety:

- Reduction of intersection crashes by 20%. This will be evaluated over the three year period of implementation, comparing both the crashes year by year as well as the overall time period compared to the three-year time period before implementation.

- Reduction of crashes involving pedestrians and other VRU by 20%.
- Reduction of crashes involving first responder vehicles by 20%.

Environment:

- A 2-3% reduction of GHG emissions related to excess fuel consumption resulting from the Dynamic Signal Optimization. This will be modeled by UMTRI to evaluate the environmental impact.

6. Alignment with USDOT Technology Areas, Goals, Focus Areas and Objectives

The Smart Intersections Project holistically is in alignment with USDOT's vision for use of funds. Table 1 below describes how the project and team support USDOT advanced transportation and congestion management technologies, goals, focus areas, and department objectives.

Table 1: Summary of Alignment with USDOT Technologies, Goals, Focus Areas, and Department Objectives

Technology Area	**Smart Intersections Project**
Advanced transportation management technologies	Dynamic Signal Optimization will demonstrate and enable the City of Ann Arbor to manage and control the performance of their vehicle and people throughput.
Advanced safety systems, including V2V and V2I communications, technologies associated with autonomous vehicles, and other collision avoidance technologies	This project will deploy DSRC, C-V2X, 5G NR C-V2X and object sensing devices to enable vehicle safety warning and vulnerable road user protection.
Electronic pricing and payment systems	Freight Signal Prioritization and Equipped Vehicle Trajectory Awareness will generate revenue. Payment for the services will be managed through the AAA server.
U. S. DOT Goal	**Smart Intersections Project**
Reduced costs and improved return on investments, including through the enhanced use of existing transportation capacity	A preliminary BCA, which will be updated upon award indicate that savings stemming from a reduction in accidents and fatalities in the City of Ann Arbor are at least $1.6M annually. In addition, FSP and EVTA will greatly improve the return on investment in Ann Arbor and the Implementation Guide for IOOs will scale nationally.
Delivery of environmental benefits that alleviate congestion and streamline traffic flow	Dynamic traffic optimization with green wave notification will reduce carbon emissions.
Measurement and improvement of the operational performance of the applicable transportation networks	Dynamic traffic optimization with green wave notification will measurably improve the operational performance of Ann Arbor's network.
Reduction in the number and severity of traffic crashes and an increase in driver, passenger, and pedestrian safety	Connected vehicle technology implementation in general will reduce the number and severity of traffic crashes. Specifically, all of the planned deployment applications target to improve safety for drivers, passengers, vulnerable road users, and first responder safety

Delivery of economic benefits by reducing delays, improving system performance and throughput, and providing for the efficient and reliable movement of people, goods, and services	Dynamic traffic optimization with green wave notification will reduce delays.
Accelerated deployment of vehicle-to-vehicle, vehicle-to-infrastructure, and automated vehicle applications, and autonomous vehicles and other advanced technologies	This project will deploy DSRC, C-V2X, 5G NR C-V2X and object sensing devices to provide public benefits and generate revenue to offset the cost of the infrastructure installation. The overarching goal of the project is to pave the way for a national CAV deployment.
Integration of advanced technologies into transportation system management and operations	The plan for deployment of dynamic traffic optimization is to integrate the technology into the City of Ann Arbor's traffic management system.
Demonstration, quantification, and evaluation of the impact of these advanced technologies, strategies, and applications towards improved safety, efficiency, and sustainable movement of people and goods	This real-world deployment will demonstrate and quantify the impact of deploying advanced connected vehicle technologies.
Reproducibility of successful systems and services for technology and knowledge transfer to other locations facing similar challenges	Implementation Guide for IOOs will transfer knowledge to all stakeholders and provide them with a playbook to invest in connected infrastructure.
Focus Areas	**Smart Intersections Project**
Installation of connected vehicle technologies at intersections and pedestrian crossing locations	VRU detection and notification will be deployed at all 21 smart intersection sites, plus at 20 existing DSRC RSU sites.
Technologies to support connected communities	VRU detection and notification, dynamic traffic optimization, emergency vehicle preemption, transit signal priority all support connected community initiatives.
USDOT Objectives	**Smart Intersections Project**
Supporting economic vitality at the national and regional level	Proven record of accomplishment with Safety Pilot Model Deployment (SPMD), the Ann Arbor Connected Vehicle Test Environment (AACVTE). Numerous jobs have been created in southeast Michigan (WSP, Savari Networks, Commsignia, Cohda Wireless, and Danlaw); brought in manufacturing of safety devices (Danlaw) and automated vehicles (Navya).
Leveraging federal funding to attract other, non-federal sources of infrastructure investment, as well as accounting for the life-cycle costs of the project	The Smart Intersections Project leverages existing vehicles and infrastructure that have been deployed by a combination of public and private funding. More importantly, the environment has attracted non-federal funding to operate and maintain the environment for 2-1/2 years.
Using innovative approaches to improve safety and expedite project delivery	All of the components of the Smart Intersections Project are innovative, but because they leverage the existing connected environment, project delivery is expedited at minimum cost.
Holding grant recipients accountable for their performance and achieving specific,	The UMTRI-led team has a proven history for developing meaningful metrics, performing in-depth risk assessment and

measurable outcomes identified by grant applicants.	mitigation, and employing industry accepted program management methods and tools to ensure that the project deliverables are met on time and on budget.

7. Statement of Work

The Smart Intersections Project team knows what it takes to stand up a deployment of this nature and size. We have demonstrated that through the success of SPMD and the longevity of the current operations and maintenance of the environment. The project is broken down into nine tasks to ensure successful completion of the project. Brief description on each of the tasks is provided below and more detailed task description can be found in Volume II of the proposal.

Task 1: Program Management. Spans the entire period of performance. This task will govern the execution and control of the project. The plan will include a full SOW with descriptions of task sand sub-tasks; a master schedule, a description of major milestones and deliverables; a staffing table, and a project budget.

Task 2: System Design. Finalize all plans for deployment including the evaluation plans, IRB approval, safety assessment, final deployment site plan, driver training plan, pre-deployment test plan, data management plan, and complete the necessary system engineering documents.

Task 3: Preparation of Vehicle Fleets and Drivers. In this task, the team will procure all hardware necessary to equip the fleet of C-V2X vehicles and maintain the current DSRC fleet. This includes supplier selection for the C-V2X OBUs and procurement of antennas, and other installation materials.

Task 4: Infrastructure Preparation. This task includes procuring all of the equipment and development of necessary software to execute the final deployment site plan.

Task 5: Pre-Deployment Testing. The main purpose of this task it to verify deployment readiness. There are many moving parts to the overall deployment, all of which need to be tested to ensure that the deployment will function to design intent prior to actually deploying at scale.

Task 6: Deployment, Data Management, and Operations Analytics. Recruit participants, equip vehicles, and install the RSUs, sensors, and necessary software. Collect, Store, and Process Data using the experimental plan. The team shall apply the data quality measures and processes defined in the Experiment Plan to convert the raw data from OBUs and RSUs into processed, quality data and ensure that those data are stored in a database, with the database schema defined in the experimental plan. Analyze data to:

- Complete benefit cost analysis for the project and submit a report to the Secretary describing the deployment and operational costs compared to the benefits and savings, and how the project has met the original expectations of projected in the deployment plan.
- Develop the Implementation Guide – a playbook and set of tools for IOOs to build and generate revenue from CV infrastructure.
- Support application development for public benefits and business model.

Task 7: Advanced V2X Technology Living Laboratory. The team will explore how 5G direct communications can enable newer applications for connected and autonomous vehicles (CAV). Vehicle and infrastructure testing will be conducted to establish a 5G New Radio (NR) C-V2X baseline. In addition, the sensor data sharing message (SDSM) will be evaluated to determine efficacy for safety applications including pedestrian detection, intersection movement assist, and

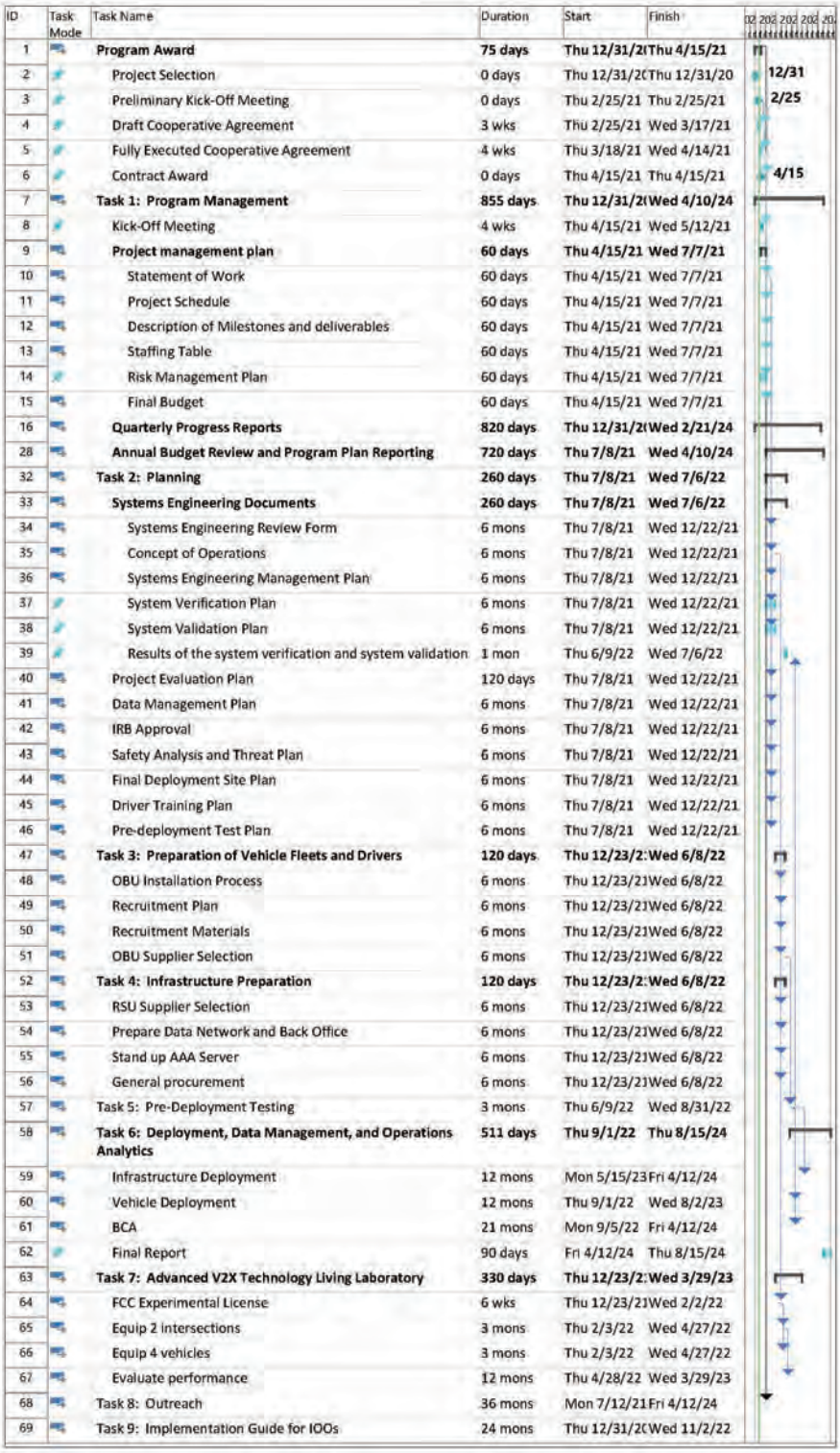
the like. Automobile manufacturers need to know the accuracy of data contained in the SDSM before they can incorporate it into their on-board applications.

Task 8: Outreach. Provide demonstrations of the technology in the real world to industry, government, academia, media and the community. We also plan to host bi-annual public webinars on projects status and findings; prepare and present technical papers and/or briefings at industry conferences; and interact with SDOs to provide technical input into emerging standards such as SAE J3224 and SAE J3186.

Task 9: Implementation Guide for IOOs. A cross-functional team will be working on the development of an Implementation Guide that will help a public jurisdiction understand the A to Z's of introducing a safety enhancing, economically and environmentally sustainable, and commercially viable V2X infrastructure.

7.1. Project Schedule

The high-level project schedule is depicted below (Figure 6). The master schedule will be delivered with the project management plan; and will include detailed tasks associated with executing all elements of the Smart Intersections Project.



ID	Task Mode	Task Name	Duration	Start	Finish
1		**Program Award**	**75 days**	**Thu 12/31/2(**	**Thu 4/15/21**
2		Project Selection	0 days	Thu 12/31/2(	Thu 12/31/20
3		Preliminary Kick-Off Meeting	0 days	Thu 2/25/21	Thu 2/25/21
4		Draft Cooperative Agreement	3 wks	Thu 2/25/21	Wed 3/17/21
5		Fully Executed Cooperative Agreement	4 wks	Thu 3/18/21	Wed 4/14/21
6		Contract Award	0 days	Thu 4/15/21	Thu 4/15/21
7		**Task 1: Program Management**	**855 days**	**Thu 12/31/2(**	**Wed 4/10/24**
8		Kick-Off Meeting	4 wks	Thu 4/15/21	Wed 5/12/21
9		**Project management plan**	**60 days**	**Thu 4/15/21**	**Wed 7/7/21**
10		Statement of Work	60 days	Thu 4/15/21	Wed 7/7/21
11		Project Schedule	60 days	Thu 4/15/21	Wed 7/7/21
12		Description of Milestones and deliverables	60 days	Thu 4/15/21	Wed 7/7/21
13		Staffing Table	60 days	Thu 4/15/21	Wed 7/7/21
14		Risk Management Plan	60 days	Thu 4/15/21	Wed 7/7/21
15		Final Budget	60 days	Thu 4/15/21	Wed 7/7/21
16		**Quarterly Progress Reports**	**820 days**	**Thu 12/31/2(**	**Wed 2/21/24**
28		**Annual Budget Review and Program Plan Reporting**	**720 days**	**Thu 7/8/21**	**Wed 4/10/24**
32		**Task 2: Planning**	**260 days**	**Thu 7/8/21**	**Wed 7/6/22**
33		**Systems Engineering Documents**	**260 days**	**Thu 7/8/21**	**Wed 7/6/22**
34		Systems Engineering Review Form	6 mons	Thu 7/8/21	Wed 12/22/21
35		Concept of Operations	6 mons	Thu 7/8/21	Wed 12/22/21
36		Systems Engineering Management Plan	6 mons	Thu 7/8/21	Wed 12/22/21
37		System Verification Plan	6 mons	Thu 7/8/21	Wed 12/22/21
38		System Validation Plan	6 mons	Thu 7/8/21	Wed 12/22/21
39		Results of the system verification and system validation	1 mon	Thu 6/9/22	Wed 7/6/22
40		Project Evaluation Plan	120 days	Thu 7/8/21	Wed 12/22/21
41		Data Management Plan	6 mons	Thu 7/8/21	Wed 12/22/21
42		IRB Approval	6 mons	Thu 7/8/21	Wed 12/22/21
43		Safety Analysis and Threat Plan	6 mons	Thu 7/8/21	Wed 12/22/21
44		Final Deployment Site Plan	6 mons	Thu 7/8/21	Wed 12/22/21
45		Driver Training Plan	6 mons	Thu 7/8/21	Wed 12/22/21
46		Pre-deployment Test Plan	6 mons	Thu 7/8/21	Wed 12/22/21
47		**Task 3: Preparation of Vehicle Fleets and Drivers**	**120 days**	**Thu 12/23/2:**	**Wed 6/8/22**
48		OBU Installation Process	6 mons	Thu 12/23/21	Wed 6/8/22
49		Recruitment Plan	6 mons	Thu 12/23/21	Wed 6/8/22
50		Recruitment Materials	6 mons	Thu 12/23/21	Wed 6/8/22
51		OBU Supplier Selection	6 mons	Thu 12/23/21	Wed 6/8/22
52		**Task 4: Infrastructure Preparation**	**120 days**	**Thu 12/23/2:**	**Wed 6/8/22**
53		RSU Supplier Selection	6 mons	Thu 12/23/21	Wed 6/8/22
54		Prepare Data Network and Back Office	6 mons	Thu 12/23/21	Wed 6/8/22
55		Stand up AAA Server	6 mons	Thu 12/23/21	Wed 6/8/22
56		General procurement	6 mons	Thu 12/23/21	Wed 6/8/22
57		Task 5: Pre-Deployment Testing	3 mons	Thu 6/9/22	Wed 8/31/22
58		**Task 6: Deployment, Data Management, and Operations Analytics**	**511 days**	**Thu 9/1/22**	**Thu 8/15/24**
59		Infrastructure Deployment	12 mons	Mon 5/15/23	Fri 4/12/24
60		Vehicle Deployment	12 mons	Thu 9/1/22	Wed 8/2/23
61		BCA	21 mons	Mon 9/5/22	Fri 4/12/24
62		Final Report	90 days	Fri 4/12/24	Thu 8/15/24
63		**Task 7: Advanced V2X Technology Living Laboratory**	**330 days**	**Thu 12/23/2:**	**Wed 3/29/23**
64		FCC Experimental License	6 wks	Thu 12/23/21	Wed 2/2/22
65		Equip 2 intersections	3 mons	Thu 2/3/22	Wed 4/27/22
66		Equip 4 vehicles	3 mons	Thu 2/3/22	Wed 4/27/22
67		Evaluate performance	12 mons	Thu 4/28/22	Wed 3/29/23
68		Task 8: Outreach	36 mons	Mon 7/12/21	Fri 4/12/24
69		Task 9: Implementation Guide for IOOs	24 mons	Thu 12/31/2(	Wed 11/2/22

Figure 6: Smart Intersections Project Schedule

8. Organizational Structure

The Smart Intersections Project is a consortium joining the University of Michigan Transportation Research Institute (UMTRI), Ford Motor Company, Toyota, Qualcomm, the City of Ann Arbor, Continental, Iteris, WSP, P3Mobility, Econolite, and Purdue University. This private-public partnership brings significant benefits and enhancements through the consortium's collective experience, knowledge from previously conducted research, knowledge from real-world deployments, as well as the existing assets that each organization brings to the Smart Intersections Project.

8.1. Organizational Structure

The Regents of the University of Michigan will be the designated recipient of the federal funds and will enter into an agreement with USDOT. Under the Regents of the University of Michigan, UMTRI will be the organization responsible for project execution. Dr. Henry Liu will oversee all elements of the project with support and guidance from co-PI Dr. James R. Sayer. This team leadership is committed to on-time delivery of results that meet or exceed USDOT's expectations. Debby Bezzina, PMP will lead the program management of the project and will employ generally accepted program management practices, such as those contained in the Program Management Book of Knowledge (PMBOK). Debby has developed reliable tools and methods to execute these practices. These tools were developed and used for the Road Departure Crash Warning (RDCW) Field Operational Test; the Integrated Vehicle Based Safety Systems (IVBSS) Field Operational Test, the SPMD; and continues to be used with the AACVTE. For each of these successful programs, lessons learned were gathered and integrated into the existing tools and methods improve their robustness for the next program. Over the course of this experience, techniques were modified from the production world to the research project environment. Ms. Bezzina will oversee adherence to PMBOK, resolve issues, and monitor and control the program.

The agreement will be administered through the University of Michigan's Office of Research and Sponsored Projects (ORSP). There are two tiers of the organization as depicted in the chart in *Figure 7*. The first tier is collaborators. These program partners are providing significant effort for the project in the form of cost share such as engineering support and test vehicles, but are not requesting any federal funds in return. Their letters of intent serve as a memorandum of understanding between parties, as a separate subcontract is not required. ORSP will track and report their cost share contributions. The second tier is sub-recipients. Each of these organizations will receive a subcontract from ORSP. ORSP will allocate their federal funds and track their respective cost share. The subcontracts are poised for immediate execution upon award, since detailed budgets and statements of work have been established. In addition to the letters of intent, each partner completed the "Sub-recipient Statement of Collaborative Intent"

required by the UM contracts office prior to submittal of the proposal. This statement further speeds along the execution of the subcontracts.

Figure 7: Smart Intersections Project Organizational Structure

All collaborators and sub-recipients will be required to adhere to federal program requirements specified in this award and will have their performance measured in relation to whether objectives of this project were met.

8.2. Organizational Roles and Responsibilities

Each of the components included in Smart Intersections Project, shown previously in Figure 2, requires expertise from a multidisciplinary team to successfully stand up the deployment. The team has thoroughly considered the roles and responsibilities of each organization, as well as specific individuals and their necessary skill sets required to capture the tasks to be accomplished and ensure their completion. The project is broken down into nine distinct tasks. The full task descriptions are included in Volume II. The RASIC chart in Figure 8 depicts the roles for each organization by task. The table shows which organization is responsible (R), approves (A), supports (S), is informed (I) or is consulted (C) for each task.

Task No.	Task Name	UMTRI	Ford	Toyota	Qualcomm	City of Ann Arbor	Continental	Iteris	Econolite	P3 Mobility	Purdue	WSP
1	Program Management	R										
2	System Design	R	S	S	S	S	S	S	S	S	S	S
3	Preparation of Vehicle Fleets and Drivers	R	S	S	S	I				S	S	
4	Infrastructure Preparation	R	I	I	I	R	S	S	S	S	S	R
5	Pre-deployment Testing	R	S	S	S	S	S	S	S	S	S	R
6	Deployment, Data Management, and Operations Analytics	R	S	S	S	R	S	S	S	S	S	R
7	Advanced V2X Technology Living Laboratory	R	S		R	S	R	S				S
8	Outreach	R	S	S	S	S	S	S	S	S	S	S
9	Implementation Guide	A	C	C						R		I

Figure 8: Smart Intersections Project RASIC Chart

9. Staffing Description

This team has deep roots in connected and automated vehicles and infrastructure that is unprecedented. A short description of each of the organizations making up the consortium, along with key personnel are included below. Full resumes are contained in Appendix B.

9.1. Organizational Descriptions

A description of each organization in alphabetical order is found below, starting with UMTRI.

9.1.1. The University of Michigan Transportation Research Institute (UMTRI)

UMTRI has conducted vehicle safety research in partnership with NHTSA, FHWA, JPO-ITS, DOE and the industry for over 50 years. UMTRI has distinguished itself as a trustworthy and capable organization that has served as prime contractor on several large, recent USDOT projects, each of which has had a group of government and industry partners, and in combination had a combined value of over $90M. In each instance, UMTRI has delivered high quality results to the USDOT on time, on budget, and on task.

- RDCW: Intelligent Vehicle Initiative Road Departure Crash Warning System FOT (2005)
- IVBSS: Integrated Vehicle-Based Safety Systems (2010)
- SPMD: Safety Pilot Model Deployment (2014)
- AACVTE: Ann Arbor Connected Vehicle Test Environment (2018)

The University of Michigan is known for its research and ability to successfully deploy connected vehicles and infrastructure. We understand what it takes to establish and maintain a deployment as demonstrated by both SPMD and AACVTE. There is no organization in the world that has as much experience with connected vehicle deployments.

9.1.2. City of Ann Arbor

The City of Ann Arbor has a history of progressive transportation systems planning, with a focus on improving safety, environmental stewardship, optimizing system operations, and providing multi-modal opportunities. In order to enhance traffic operations of the existing roadway network, the City began systematically installing a fiber-optic traffic signal network in 1998. Now encompassing over 160 traffic signals and growing, this system enables centralized control of signal operations along key corridors throughout the City. Many of these corridors have been incorporated into the City's SCOOT adaptive signal control system.

9.1.3. Continental

As a reliable partner of all major OEMs and tire manufacturers, Continental provides intelligent, sustainable, safe, comfortable and affordable technologies for transporting people and their goods. Continental has a large R&D footprint for vehicle networking, connectivity and autonomous mobility in the Metro Detroit area. In 2019, the corporation generated sales of €44.5 billion with its five divisions, Chassis & Safety, Interior, Powertrain, Tire, and ContiTech. Continental

currently employs more than 18,000 people in 54 facilities within US (tbc) and 242,000 around 59 countries. On automated driving, Continental's advanced driver assistance systems provide the basis for the automated driving of the future.

9.1.4. Econolite Group

Econolite has been a recognized leader, innovator, manufacturer and supplier of transportation management solutions since the company's inception in 1933. Econolite's portfolio of product solutions includes traffic management and maintenance management software, vehicle detection, vehicle and pedestrian signals, traffic controllers and cabinets. Econolite helped establish the industry standards that set the groundwork for the technological advancements of connected vehicles, especially for the vehicle-to-infrastructure (V2I) communication with contributions to SAE (J2735/J2945). Econolite has been involved with multiple connected vehicle deployments, including: deployment of ITS systems in the Mcity test facility; deployment of SPaT equipped controllers as part of the SPMD; MMITSS Pooled Fund Study with the University of Arizona; and the Battelle-led SPaT Interface development and now V2I Reference Implementation.

9.1.5. Ford Motor Company

The Ford Motor Company is an American-based automobile manufacturer; its Ford marque claims the spot as the most valuable American car brand, and fifth most valuable car brand worldwide. The company sold over 2.6 million vehicles and generated just under 150 billion U.S. dollars in revenue in 2015. Ford Motor Company has 67 facilities worldwide and employees 199,000. Ford aggressively is pursuing efforts to be a leader in connectivity, mobility, autonomous vehicles, the customer experience and data and analytics. For over 20 years, Ford has been working as the prime contractor with the Department of Energy and the Department of Transportation on successful research & development, cooperative agreements.

9.1.6. Iteris

Iteris applies cloud computing, artificial intelligence, advanced sensors, advisory services and managed services to achieve safe, efficient and sustainable mobility. Our end-to-end solutions monitor, visualize and optimize mobility infrastructure around the world to help ensure that roads are safe, travel is efficient, and communities thrive.

9.1.7. P3MOBILITY

P3Mobility provides a software platform, software tools and consulting services to support the introduction of a commercial model to the V2X eco-system. Founded in 2018, they were awarded a flagship CV project in Oakland County Michigan that allowed them to conduct extensive stakeholder engagement and market research targeted at understanding the barriers and opportunities with regards to privately financing infrastructure. They have been awarded grants by both the State of Michigan and the Province of Ontario (AVIN) in support of technology testing which is taking place at MCity in Michigan and on a testbed in Peterborough, Ontario.

9.1.8. Purdue

Purdue University is a premier engineering institute and its College of Engineering is ranked 7th in the U.S. Purdue is in a position to lead with potential partners in Indiana and the nation in the development of connected and autonomous vehicle research, testing, evaluation and

implementation. Through the Joint Transportation Research Program (JTRP) and NEXTRANS Center and Center for Connected and Automated Transportation partnership, the faculty, staff, and students of Purdue have the multidisciplinary expertise required to develop and build the smart interconnected technologies that are needed for our roads, vehicles, and the cloud.

9.1.9. Qualcomm:

Qualcomm invents breakthrough technologies that transform how the world connects, computes and communicates. Qualcomm is an R&D engine and our foundational technologies have powered the smartphone revolution and connected billions of people for over 30 years. Our technology is in virtually every smartphone in the world. We invented CDMA, pioneered 3G and 4G, and are leading the way to 5G and a new era of intelligent, connected devices. Cellular V2X (C-V2X) technology connects vehicles to everything and is an important enabler in the vision for always-connected, automated vehicles of the future. Qualcomm is committed to supporting safe, connected automotive transportation including applications connecting V2V, V2P, V2I, and to the network (V2N). Building on the Qualcomm Technologies' leadership in 3G/4G LTE, carmakers and infrastructure providers have a clear migration path to 5G.

9.1.10. Toyota

Toyota has been a part of the cultural fabric in the U.S. and North America for 60 years and is committed to advancing sustainable, next-generation mobility through our Toyota and Lexus brands. During that time, Toyota has contributed to world-class design, engineering, and assembly of more than 36 million cars and trucks in North America, where we operate 14 manufacturing plants (10 in the U.S.) and directly employ more than 47,000 people (more than 37,000 in the U.S.). Our 1,800 North American dealerships (nearly 1,500 in the U.S.) sold more than 2.7 million cars and trucks (2.4 million in the U.S.) in 2017 – and about 87 percent of all Toyota vehicles sold over the past 15 years are still on the road today.

9.1.11. WSP

WSP has been working with key players across the world to better understand the impact of connected and driverless vehicles on local environments. WSP partners with state and local transportation agencies and offers strategic and operational guidance covering numerous key areas including: current state of connected and automated vehicle technology; new mobility services and associated activities; public-private partnerships for pilot testing and technology development; and long-range policies and plans supporting strategic, financial and operations planning. WSP was, and continues to be, a key partner with the UM, the City of Ann Arbor and MDOT in the development of the SPMD and the AACVTE.

9.2. Key Personnel

Henry Liu, PhD (UMTRI): Principal Investigator, Dr. Liu is Director of the Center for Connected and Automated Transportation – CCAT (Regional 5 UTC); Professor, Department of Civil and Environmental Engineering; Research Professor, UMTRI. Prof. Liu conducts interdisciplinary research at the interface between civil and mechanical engineering. Specifically, his scholarly interests concern traffic flow monitoring, modeling, and control, as well as testing and evaluation of connected and automated vehicles. He has published more than 100 refereed journal papers. Dr. Liu is the managing editor of Journal of Intelligent Transportation Systems and

an associate editor of Transportation Research Part C. His research has been sponsored by the NSF, US DOT/FHWA/NHSTA, US DOE, CAMP, and Mcity.

James Sayer, PhD (UMTRI): Co-PI, Dr. Jim Sayer of UMTRI. He has held major leadership roles in all the above-mentioned USDOT sponsored programs, including serving as PI on IVBSS, SPMD and AACVTE. He serves as the Director and a Research Scientist in UMTRI. He also serves as the lead for the University's Smart Mobility Education Initiative. Dr. Sayer has 24 years of experience working on USDOT sponsored programs that focus on the field operational testing or deployment of advanced transportation technologies. His interests and experience in advanced vehicle safety systems, connectivity, and automation led him to conceive of, design, and oversee the construction of Mcity – the world's first real-world testing facility for the evaluation of connected and automated vehicle technologies.

Debby Bezzina, PMP (UMTRI): Ms. Bezzina is Senior Program Manager for the AACVTE – one of the largest to-scale deployments in the world. Debby and her team have helped shape the future of transportation by deploying and proving out DSRC-based connected vehicle technology. The data collected from the Ann Arbor deployment (formerly SPMD) led to the NPRM to require connected vehicle technology on all new passenger vehicles (Federal Register NHTSA-2016-0126). Debby Bezzina also serves as the Managing Director of CCAT, which was awarded the Region 5 UTC. CCAT provides national and regional leadership for connected and automated transportation research, science, education, training, and deployment.

Shailish Patil, PhD (Qualcomm): is a Principal Engineer at Qualcomm and leads 5G for automotive applications research at Qualcomm. This includes leading research and 3GPP standardization of C-V2X. Previously, as a rapporteur, he led the standardization of device to device communication in 3GPP LTE. This was for the first time that device-to-device communication was standardized in any cellular standard. He has 121 granted U.S. patents and a total of 565 granted patents worldwide. Shailesh got his PhD and MS from University of Texas at Austin in 2006 and 2004 respectively. He has been with Qualcomm since 2006.

Martin Nathanson, Chief Technology Officer (P3Mobility): Martin Nathanson has worked in automotive telematics since 1997 and has built a significant and expanding patent portfolio in this area. He is primarily focused on the evolution and development of wireless technologies that are converging to revolutionize the field of automotive transportation. He has both an in-depth technical understanding as well as a broad business and market understanding of the emerging trends in connected and intelligent transportation. Martin has been successful at filing and prosecuting strategically important patents in this area. Martin holds a Bachelor of Engineering Degree from University of Waterloo and a Master in Urban Planning from McGill University.

9.3. Primary Point of Contact

Dr. Henry Liu, CCAT Director will be the primary point of contact for the project. His contact information is below.

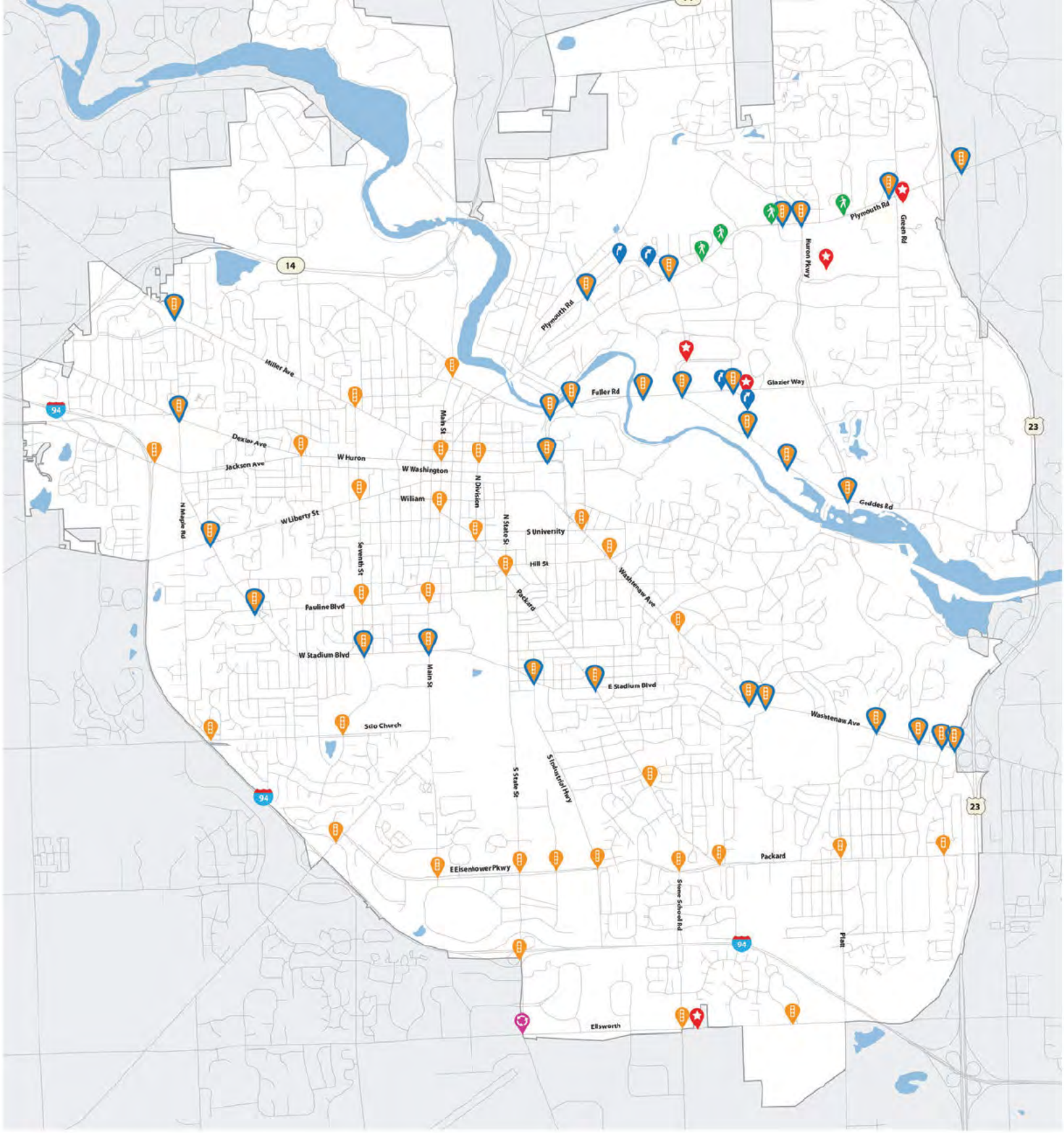
2901 Baxter Road
Ann Arbor, Michigan 48109-2150
Email: henryliu@umich.edu

Office Phone: (734) 764-4354
Mobile Phone: (651) 260-5876

Smart Intersections: Paving the Way for CAV Deployment

Appendix A:

Deployment Map



Intersection Broadcasting SPaT/MAP

Curve Speed Warning Broadcasting TIM

Pedestrian Mid-Block Crosswalk Broadcasting PSM

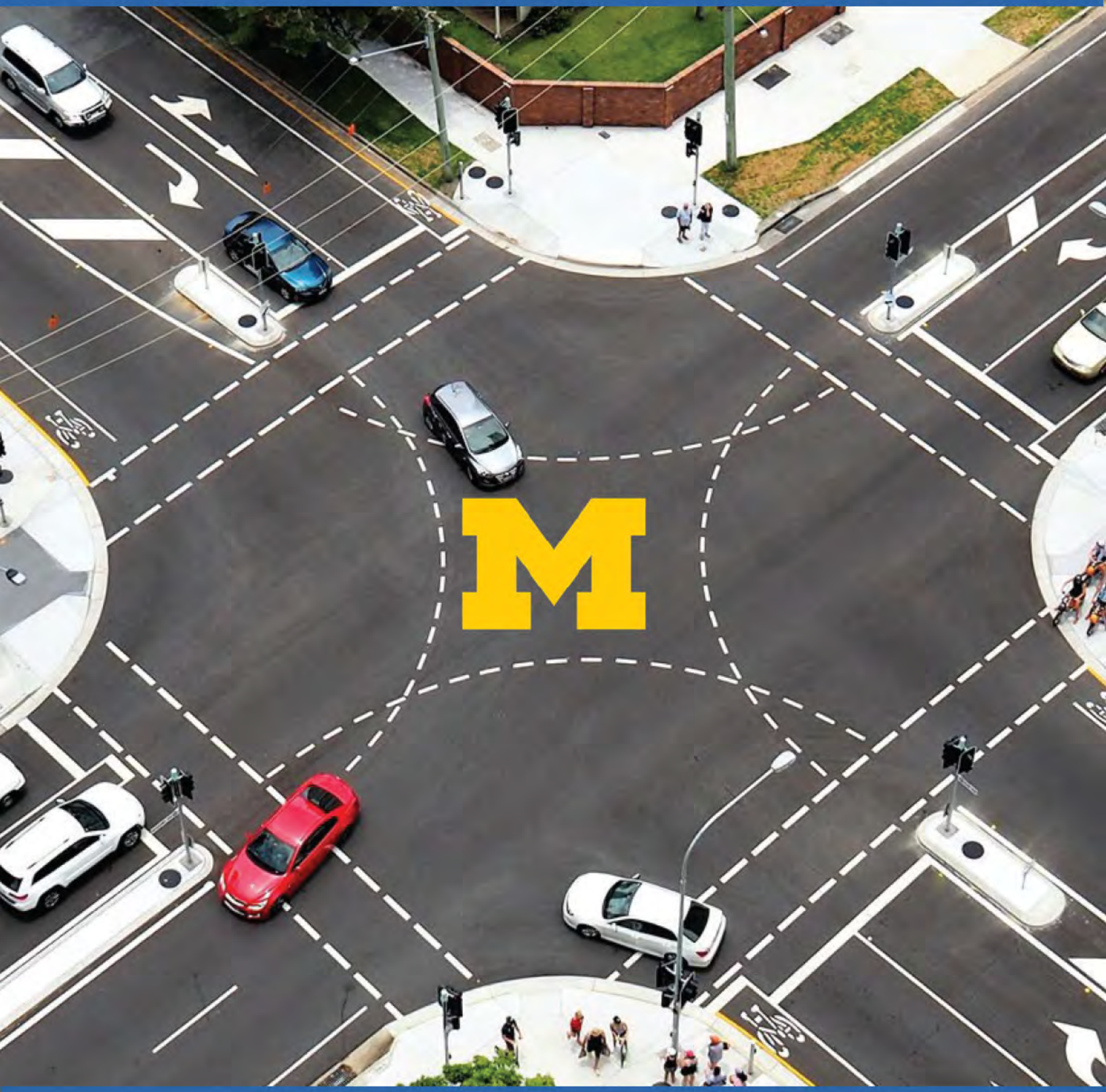
Roundabout Broadcasting MAP

Staging or Test Site Broadcasting Various Message Types Without Security Enabled

Smart Intersection

A-1

Smart Intersections: Paving the Way for a National CAV Deployment



Appendix B:

Résumés

UNIVERSITY OF MICHIGAN
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HENRY X. LIU, PH.D.
Phone: 734-764-4354, Email: henryliu@umich.edu

Dr. Henry Liu is a tenured Professor of Civil and Environmental Engineering at the University of Michigan, Ann Arbor. He is also a Research Professor at the University of Michigan Transportation Research Institute and the Director for the Center for Connected and Automated Transportation (USDOT Region 5 University Transportation Center). Liu received his Ph.D. degree in Civil and Environmental Engineering from the University of Wisconsin at Madison in 2000 and his B.S. degree in Automotive Engineering from Tsinghua University (China) in 1993. Prof. Liu conducts interdisciplinary research at the interface between civil and mechanical engineering. Specifically, his scholarly interests concern traffic flow monitoring, modeling, and control, as well as testing and evaluation of connected and automated vehicles. He has published more than 100 refereed journal papers and his publications have been citied over 6000 times according to Google Scholar Citations. Prof. Liu is also one of the top 50 leading authors in the past 50 years (1969-2019) in the prestigious Transportation Research journal. Dr. Liu is the managing editor of Journal of Intelligent Transportation Systems and an associate editor of Transportation Research Part C.

Education

B.S. in Automotive Engineering, Tsinghua University, P. R. China, 1993
Ph.D. in Civil and Environmental Engineering, University of Wisconsin at Madison, 2000

Positions/Employment

Director, Center for Connected and Automated Transportation, University of Michigan, Nov.2016 – Present
Professor (with Tenure), University of Michigan, Ann Arbor, September 2014 – Present
Research Professor, University of Michigan Transp. Research Institute, September 2014 – Present
Associate Professor (with Tenure), University of Minnesota, August 2011 – August 2014
Assistant Professor, University of Minnesota, August 2005 – July 2011
Assistant Professor, Utah State University, August 2003 – July 2005
Postdoctoral Researcher, University of California, Berkeley, August 2000 – July 2003
Part-Time Lecturer, University of Southern California, January 2002 – May 2003
Graduate Research Assistant, University of Wisconsin at Madison, August 1997 – July 2000
Assistant Engineer, Changchun Automotive Research Institute, China, August 1993 – July 1995

Research Interests

- Dynamic modeling and simulation of traffic system, including traffic flow theory and network traffic assignment;
- Traffic control system design and optimization;
- Cyber-physical transportation systems, including connected vehicle applications, eco-driving and vehicle powertrain management.
- Testing and evaluation of connected and automated vehicles

Professional Activities

2016 – Present Managing Editor, Journal of Intelligent Transportation Systems

2011 – Present Associate Editor, Transportation Research Part C: Emerging Technologies

Recent Research Grants and Contracts

1. Project Title: *USDOT Region 5 University of Transportation Center: Center for Connected Automated Transportation*
   Funding Agency: *US Department of Transportation,* PI: *H. Liu ,* Total Funding: *~$13,000,000*
   Duration: *October* 2016 – *September 2022*

2. Project Title: On-Road Motor Vehicle Assessment Methods
   Funding Agency: *National Highway Traffic Safety Administration,* PI: C. *Flannagan (Co-PI: D. LeBlanc and Y. Feng of UMTRI, and H. Liu of CEE)*
   Total Funding: *~$1,047,106,* Duration: *October* 2019 – *January 2022*

3. Project Title: *Energy Impact of Connected and Automated Vehicle Technologies*
   Funding Agency: *US Department of Energy,* PI: *H. Peng (Co-PI: D. LeBlanc, H. Liu, J. Sayer)*
   Total Funding: *$2,600,000,* Duration: *October* 2015 – *December 2018*

Recent Refereed Journal Articles

1. Feng S., Feng Y., Yan, X., Shen, S., Xu, S., Liu, H.X. (2020) Safety assessment of highly automated driving systems in test tracks: A new framework, Accident Analysis and Prevention, 144, https://doi.org/10.1016/j.aap.2020.105664.
2. Li, W.,Ban, J.X., Zheng, J.F., Liu, H.X., Gong, C., and Li, Y. (2020) Real-Time Movement-Based Traffic Volume Prediction at Signalized Intersections, ASCE Journal of Transportation Engineering, Part A: Systems, 146 (8), DOI: 10.1061/ JTEPBS.0000384.
3. Feng S., Feng Y., Yu, C., Zhang Y., and Liu H.X. (2020). Testing Scenario Library Generation for Connected and Automated Vehicles, Part I: Methodology. IEEE Transactions on Intelligent Transportation Systems, DOI: 10.1109/TITS.2020.2972211.
4. Feng S., Feng Y., Sun, H.W., Bao, S., Zhang Y., and Liu H.X. (2020). Testing Scenario Library Generation for Connected and Automated Vehicles, Part II: Case Studies. IEEE Transactions on Intelligent Transportation Systems, DOI: 10.1109/TITS.2020.2988309.
5. Wang X., Shen S., Feng Y., Bezzina D., Sayer J., and Liu H.X. (2020). A Data Infrastructure for Connected Vehicle Applications. Transportation Research Record, Accepted.
6. Zhao, Y., Zheng, J., Wong, W., Wang, X., Meng, Y., & Liu, H. X. (2019). Estimation of queue lengths, probe vehicle penetration rates, and traffic volumes at signalized intersections using probe vehicle trajectories. Transportation Research Record, 2673(11), 660-670.
7. Yu, C., Sun, W., Liu, H. X., & Yang, X. (2019). Managing connected and automated vehicles at isolated intersections: From reservation-to optimization-based methods. Transportation Research Part B: Methodological, 122, 416-435.
8. Feng, S., Sun, H., Zhang, Y., Zheng, J., Liu, H. X., & Li, L. (2019). Tube-based discrete controller design for vehicle platoons subject to disturbances and saturation constraints. IEEE Transactions on Control Systems Technology. DOI: 10.1109/TCST.2019.2896539.
9. Wong W., Shen S., Zhao Y. and Liu, H. X. (2019). On the estimation of connected vehicle penetration rate based on single-source connected vehicle data. Transportation Research Part B: Methodological 126, 169-191.
10. Yu, C., Feng, Y., Liu, H. X., Ma, W., & Yang, X. (2019). Corridor level cooperative trajectory optimization with connected and automated vehicles. Transportation Research Part C: Emerging Technologies, 105, 405-421.

UNIVERSITY OF MICHIGAN
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NAME James Richard Sayer

TITLES Director and Research Scientist, UMTRI
Adjunct Professor, Civil and Environmental Engineering

EDUCATION Ph.D., Industrial and Systems Engineering, Virginia Tech, 1993
M.S., Industrial and Systems Engineering, Virginia Tech, 1991
B.S., Biopsychology, The University of Michigan, 1988

RESEARCH INTERESTS

Dr. Sayer conducts both basic and translational research in the areas of advanced vehicle safety systems, human interaction with highly automated vehicles, connected vehicle and infrastructure technology, naturalistic driving behavior, driver distraction, and pedestrian safety. His research findings are utilized by vehicle manufacturers and suppliers in support of the design, development, and deployment of safety technologies, as well as by government agencies in establishing policies and regulations related to vehicle safety technologies, driver behavior, and the deployment of connected vehicle technology. Dr. Sayer was the lead architect of the autonomous and connected vehicle test facility known as Mcity (2013 – 2015) having conceived of, designed, and overseen its construction. Dr. Sayer has served as the Principal Investigator of the Ann Arbor Connected Environment (2019 – 2020), the U.S. DOT's Ann Arbor Connected Vehicle Test Environment (2015 – 2019), and U.S. DOT's Connected Vehicle Safety Pilot Model Deployment program (2011 – 2015).

EMPLOYMENT

2016 – Present:	Director of UMTRI
2014 – Present:	Adjunct Professor of Civil and Environmental Engineering, The University of Michigan
2013 – 2016:	Deployment Director, Michigan Mobility Transformation Center (Mcity), The University of Michigan
2012 – 2016:	Research Scientist, Group Head, The University of Michigan Transportation Research Institute, Human Factors Group
2008 – 2012:	Associate Research Scientist, The University of Michigan Transportation Research Institute, Human Factors Division
1993 – 2008:	Assistant Research Scientist, The University of Michigan Transportation Research Institute, Human Factors Division

RELATED SERVICE COMMITMENTS

2018 – 2020:	Member of the Autonomous and Shared Mobility Forum, Transportation Research Board
2018 – 2019:	State of Michigan Mobility Steering Committee
2017 – Present:	Chair, Institutional Autonomous Systems Committee, University of Michigan Mobility Coordinating Committee
2009 – 20011:	Chair, UM Behavioral Sciences Institutional Review Board

RELATED SPNSORED RESEARCH EFFORTS

Investigation into U.S. Real-World Lane Change Behavior for Automated Freeway Driving, Principal, Investigator Ford-University of Michigan Alliance (2016), Awarded $199,247 over 1.5 years.

Energy Impact of Connected and Automated Vehicle Technologies, Co-Principal Investigator, U.S. Department of Energy (2015), Awarded $343,788 over 3 years.

Ann Arbor Connected Vehicle Test Environment, Principal Investigator, Federal Highway Administration, U.S. DOT, (2015), Awarded $9 million in Federal funds, with an additional $6.7 million in cost share over 3 years.

Connected Vehicle Safety Pilot Model Deployment, Principal Investigator, Federal Highway Administration, U.S. DOT, (2011), Awarded $25.5 million in Federal funds, with an additional $5.5 million in cost share over 3 years.

Integrated vehicle-based safety systems program field operational test (IVBSS FOT). Principal Investigator. National Highway Traffic Safety Administration (2005). Awarded $25.3 million in Federal funds, with an additional $7.1 million in cost share, over 5.5 years.

An intelligent vehicle initiative road departure crash warning system field operational test (RDCW FOT). Co-Principal Investigator. Federal Highway Administration (2001). Awarded $18.1 million over 3 years.

RELATED PUBLICATIONS

Yu, B., Bao, S., Feng, F., & Sayer, J.R., (2019). Examination and prediction of drivers' reaction when provided with V2I communication-based intersection maneuver strategies. *Transportation Research Part C: Emerging Technologies*, 106, 17-28.

Jones, M.L.H, Sienko, K., Ebert, Hamilton, S., Kinnaird, C, Miller, C. Lin, B., Park, B.K., Sullivan, J., Reed, M.P., and Sayer, J.R. (2018). Development of a Vehicle Based Experimental Platform for Quantifying Passenger Motion Sickness during Test Track Operations. SAE Technical Paper, 2018-01-0028.

Jermakian, J. S., Bao, S., Buonarosa, M. L., and Sayer, J. R. (2017). Effects of an integrated collision warning system on teenage driver behavior. *The Journal of Safety Research*, 61, 65-75.

Bezzina, D., & Sayer, J. R. (2015, June). *Safety pilot model deployment: Test conductor team report*. (Report No. DOT HS 812 171). Washington, DC: National Highway Traffic Safety Administration.

Sayer, J. R., David J. LeBlanc, Scott E. Bogard, Dillon S. Funkhouser, Shan Bao, Mary Lynn Buonarosa, and Adam D. Blankespoor. Integrated Vehicle-Based Safety Systems (IVBSS) Field Operational Test Final Program Report, University of Michigan Transportation Research Institute (UMTRI), Ann Arbor, MI. Sponsored by U.S. Department of Transportation, Research and Innovative Technology Administration, ITS Joint Program Office, Washington, D.C., June 2011. DOT HS 811 482, UMTRI-2010-36.

UNIVERSITY OF MICHIGAN
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Debby Bezzina

Professional Preparation

University of Michigan Dearborn, Bachelor of Science, Electrical Engineering, 1986
University of Michigan Ann Arbor, Master of Business Administration, 1995

Appointments

Dates	Position(s)	Organization
December 2016 – Present	Managing Director, Center for Connected and Automated Transportation	University of Michigan Transportation Research Institute
May 2015 – Present	Connected Environment Working Group Lead	University of Michigan Mcity
September 2011–Present	Sr. Program Manager, Ann Arbor Connected Vehicle Test Environment	University of Michigan Transportation Research Institute
August 2000 – September 2011	Engineering Manager, Advanced Driver Awareness Systems	Visteon Corporation
September 1994 – August 2000	Design and Release Engineer, Truck Electronics	General Motors Corporation
March 1987 – September 1994	Systems Engineer, Engine Engineering	Ford Motor Company

Products

Kuciemba, Steve, Timcho, Tom, McLaughlin, Katie, Perry, Frank, and Bezzina, Debby. V2X Communications in the 5.9 GHz Spectrum. March 2020.

X. Wang, S. Shen, Y. Feng, D. Bezzina, J. Sayer, and H.X. Liu, A Data Infrastructure for Connected Vehicle Applications. Accepted for the 2020 TRB Annual Meeting.

Bezzina, Debby, Sayer, James. *Successful Management of a Connected Vehicle and Infrastructure Model Deployment.* October 2014. 2014 ITS World Congress Proceedings.

Bezzina, Debby, Sayer, James. *Safety Pilot Model Deployment: Test Conductor Team Report.* June 2015. Report No. DOT HS 812 171.

U.S. Patent #US008831870 Vehicle Collision Avoidance and Mitigation System, September 9, 2014.

Synergistic Activities

SAFETY PILOT MODEL DEPLOYMENT (SPMD). Mrs. Bezzina was responsible for the day to day operations for deploying DSRC-based connected vehicle technology in Northeast Ann Arbor. As Senior Program Manager, responsibilities for this successful program included:

- Leading multidisciplinary technical team of 50+ people from 12 organizations:

- Performing significant industry outreach in the way of numerous public speaking engagements and connected vehicle demonstrations
- Employing generally accepted Program Management principles (PMBOK) to initiate, plan, execute, monitor and control, and close the overall program.
- Lessons learned from this project were incorporated into industry standards including RSU 4.1, SAEJ2935, SAEJ2945, and IEEE1609.x. This project also was the starting point for the production SCMS system developed by CAMP and stood up by Green Hills (ISS).
- Results from this project from this project were used to write:
    - FHWA-JPO-16-363 - Safety Pilot Model Deployment Lessons Learned and Recommendations for Future Connected Vehicle Activities
    - DOT HS 812 222 - Independent Evaluation of Light-Vehicle Safety Applications Based on Vehicle-to-Vehicle Communications Used in the 2012–2013 Safety Pilot Model Deployment
- SPMD results led to the Notice of Proposed Rulemaking for FMVSS 150, making V2V technologies standard on all new vehicles (Docket No. NHTSA–2016–0126).

MAINTAIN, OPERATE AND SUSTAIN THE ANN ARBOR CONNECTED VEHICLE TEST ENVIRONMENT (AACVTE). Mrs. Bezzina continued her role as Senior Program Manager to transition from a model deployment to an early operational deployment. In additional to the continuing roles for SPMD above, Debby and her team have been very active in the industry to lead efforts to implement the changing DSRC standards. All of the equipment from the Safety Pilot Model Deployment was decommissioned and replaced with new hardware that meets the 2016 industry standards. The AACVTE will expand the infrastructure footprint from 25 sites in Northeast Ann Arbor to 75 sites encompassing all of Ann Arbor (27 square miles). Additionally, 2500 DSRC-equipped vehicles are deployed. AACVTE is the first fully compliant real-world DSRC deployment that interfaces with the Production Security Credential Management System and is the standard for a national deployment. During this project, Bezzina has participated in approximately 350 outreach engagements and technical exchanges. The outreach activities include events with academia, government, industry, and media. The events range from STEM activities for youth to adult enrichment for seniors. We have held workshops for the CV pilots to download our knowledge of an operational connected environment to feed into their concept of operations, scope, and master schedules.

CENTER FOR CONNECTED AND AUTOMATED TRANSPORTATION (CCAT). As the Managing Director of CCAT, I have developed the process and criteria for awarding $2.7M annually for research for connected and automated vehicles, infrastructure, and mobility. I have also developed the CCAT technology transfer plan including metrics and the establishments of the technology advisory board. The board is made up of executives from industry, government, and academia. The board advises CCAT on what research should be conducted and reviews all of the proposals for merit and technology transfer propensity. In addition to funding much needed research, CCAT also has strong ties to leadership development. I have supported student chapters by arranging for industry experts to speak at lunch-and-learn meetings and have also sponsored several students to attend the TRB annual meeting.

Affiliations and Registrations

Program Management Professional, Program Management Institute, May 2010 - Present
Board of Directors, ITS Michigan, January 2015 – Present
Vice President, ITS Michigan, June 2017-May 2018
President, ITS Michigan, June 2018-May 2019
Program Chair, ITS Michigan June 2018-February 2020

SHAILESH PATIL

Email Id: patil.s.shailesh@gmail.com Phone No: 9082685954

Summary:

- Lead for 5G for automotive research and 3GPP standardization at Qualcomm. This includes Cellular Vehicle to Everything communication (C-V2X).
    - The work on C-V2X has enabled Qualcomm to become the industry leader for the technology.
    - Leading an independent project with a separate multi-million dollar budget and a team of ~45 members located across multiple time zones.
    - Responsibilities include driving the 5G for vehicular technology roadmap, creating technology demonstrations, IP portfolio development, detailed design, 3GPP standardization, technology transfer to development team, trial design & support, customer interaction, and technology promotion.

- Proven industry wide leadership in wireless research and standardization.
    - Rapporteur of Release 12 & 13 LTE Direct items. This work lead to the standardization of "sidelink" (device to device link) for first time in a cellular standard. This technology formed the basis for V2X communication in 3GPP.

- Co-inventor on 153 pending US (total 780 worldwide) patent applications and 121 granted US patents (total 567 worldwide). Co-author on several research publications. Invited panelist and speaker at many international forums.

Education:

- Ph.D., ECE, University of Texas at Austin, May 2006
- M.S., ECE, University of Texas at Austin, May 2004
- B.E., ECE, Netaji Subhas Institute of Technology (NSIT), Delhi University, May 2001

Professional Experience:

Principal Engineer/Mgr., Qualcomm Wireless R & D, San Diego, Nov. 2016 to present

- Lead for 5G for automotive research and 3GPP standardization at Qualcomm. This includes Cellular Vehicle to Everything communication (C-V2X).
    - Leading an independent R&D project with a separate multi-million dollar budget

and a team of ~45 members located across multiple time zones.

– Leading research and standardization of 5G NR V2X. This includes:
  - Developing applications and quantifying the need for 5G NR V2X for autonomous driving, and demonstrating the concepts
  - Detailed system design, creating an IP portfolio and 3GPP standardization.
– Leading the development of 5G NR V2X aligned prototype
  - Developed and demonstrated the world's first prototype with distance based reliability feature of 5G NR V2X
- Lead the research and standardization of LTE V2X. This includes:
  - This work has led to world's first commercial offering of the LTE based C-V2X modem by Qualcomm and has become part of Qualcomm's mainline product offering.
  - Provided technological guidance to world's first shoot out between LTE V2X and DSRC (a competing V2X technology). The trial successfully demonstrated the significant advantage of LTE V2X compared to DSRC.
  - Lead 3GPP standardization of LTE V2X to make sure that the design is based on Qualcomm's proposals. This was enabled by Qualcomm being the only company to provide comprehensive comparison to DSRC.
  - Deeply involved in many stages of product development including product definition, technology transfer, and validation.
  - Deeply involved in many stages of commercialization including trial design, customer interaction, and technology promotion.
– Researching other technologies targeting 5G with automotive applications.

Senior Staff Engineer/Mgr., Qualcomm New Jersey Research Center, Nov. 2012 to 2016
- Qualcomm's lower layer lead for cellular based D2D and V2X research
  - Driving lower layer technology roadmap and future research topics.
  - Developed lower layer IP portfolio for these technologies.
  - Supervised parts of prototype development.
  - Acting as a point of contact for the product team integrating these features into Qualcomm's modems.
  - Involved in technical marketing and product requirement definition.
- LTE rapporteur of D2D study and work items for Release 12 & 13.
  - Successful completed the study and work items. D2D was the biggest item of Release 12 LTE.
  - Very successful in getting several of Qualcomm's design ideas accepted as part of LTE.
  - Have chaired several offline sessions and discussions successfully.

Invited Talks:

- Invited panelist at Autonomous Vehicle Symposium 2020
- Invited speaker at DAC 2020
- Invited speaker at ETSI ITS Workshop March 2018
- Invited panelist at Autonomous Vehicle Symposium 2018
- Invited speaker and panelist at IEEE 5G World Forum 2018
- Keynote speaker and invited panelist at IEEE VNC 2017

Conference Proceedings:

- L. Gao, Y. Li, J. Misener, **S. Patil**, "C-V2X based basic safety related ITS spectrum analysis", *IEEE VTC 2017*.
- V. Nguyen, **S. Patil**, K. Gulati, Z. Wu, L. Jiang, S. Baghel, D. Malladi, J. Li, "A Comparison of Cellular Vehicle-to-Everything and Dedicated Short Range Communication", *IEEE VNC 2017*.
- A. Ali, L. Jiang, **S. Patil**, J. Li, R. Heath, "Vehicle-to-Vehicle Communication for Autonomous Vehicles: Safety and Maneuver Planning", IEEE VTC 2018.

Martin Nathanson CV

PROFILE

Founder and Chief Technical Officer - Paxgrid Telemetric Systems
Chief Technology Officer, P3Mobility
Westmount, QC
paxgrid@rogers.com - 514 808 2005

I have been focused throughout my career on the convergence of wireless networking with micro-processor-based technologies particularly in the field of automotive transportation and more broadly in the space which has come to be known as the Internet of Things. I have worked in automotive telematics since 1997 and have have built a patent portfolio in this area which is still expanding. I have both an in-depth technical understanding as well as broad business and market understanding of the emerging trends in connected and intelligent transportation. I have been successful at filing and prosecuting strategically important patents in this area and I am acknowledged by IP attorneys as having exceptional skills in terms of draft patent disclosures and claims. I am in a position to apply this broad range of skills to the conceptualization, development, IP protection and marketing of new technologies that leverage the potential of wireless Internet connectivity.

EDUCATION

MSc in Urban Transportation
McGill University
1978

BSc in Transportation Engineering
University of Waterloo
1976

WORK EXPERIENCE

Chief Technical Officer (contractual)
P3Mobility - 2018 to Present

Responsible for conceptualization, architectural design and implementation of all components of

P3Mobility Smart Road infrastructure, including AAA Server and enhanced V2I Hub.

Founder and Chief Technical Officer Paxgrid Telemetric Systems - 1999 to Present

Developed IP, system architecture and embedded software for automotive telematics, encompassing GPS- based location monitoring, and on-board diagnostics (OBD) for light- and heavy-duty vehicles. Designed and Implemented object-oriented embedded software in OBD-II dongle (ARM ST-Micro microcontroller) for remote wireless communications including over-the-air firmware updates. Designed, participated in and and supervised implementation of back-office database system for fleet management of telematics-equipped vehicles (Java/Netbeans environments). Developed prototype applications for DSRC (Dedicated Short- Range Communications) devices, both on-board vehicles (OBUs) and stationary units (RSUs), operating on embedded Linux platform. Conceptualized, drafted and prosecuted a range of patents constituting original methods for extending the scope of existing standards in the context of mobile data communications applications.

Since February 2014, served as technical advisor to the Oakland County Connected Vehicle Task Force, an initiative of the Oakland County, (Michigan) executive to develop a sustainable business model for deployment and operation of DSRC infrastructure. Conceived the architecture that enables roadway operators to create revenue streams to from operations of DSRC infrastructure, sufficient to offset both capital and operating costs. Prepared all technical material for presentations to Tier 1s and other partners. Proposed and drafted all submissions to FCC by Oakland County Connected Vehicle Task Force regarding both proceedings relative to DSRC (Dockets 13-49 and RM-11771, see https://www.fcc.gov/ecfs/search-proceedings)

Patent Consultant
Independent - August 2016 to Present

Draft of U.S. patent application for Toronto-based opinion polling company. Client had developed unique approach to opinion surveying and implemented undocumented Single Page Application (SPA) using MEAN (Mongo DB, Express.js, Angular.js, Node.js) stack for client-side Web programming. Established documentation of architecture based on interviews of client's lead software architect and back-end data survey data analyst and made additional conceptual contribution to patentable subject matter. Wrote claims and worked with leading Washington-based IP attorney to complete and file application with USPTO.

KNOWLEDGE AND SKILL SET

Protocol Specifications : TCP/IP, IPv6, SNMP (network management), IEEE 802.11, IEEE 1609 (WAVE) and SAE-2735 (V2V and V2I) (10+ years)

Programming Languages : C, C++, C#, Java (10+ years)

Security: PKI architectures, Secure Socket Layer public-private key encryption. (10+ years)

Database knowledge : MySQL (design of databases and Java-based SQL) (5 years)
UML : object-oriented concepts, classes, object interaction (10+ years)

Embedded system : real- time operating systems and low-level development with ARM processors (6

years), Smartphone OS platforms (particularly Android) (2 years)

Automotive: extensive knowledge of OBD-II protocols, CAN bus (ISO-15765-1,4) and SAE J-1939 (heavy equipment), GPS (NMEA and uBlox UBX protocol) (10+ years)

Wireless: extensive knowledge of wireless Internet connectivity technology, interface to 2G/3G M2M equipment (primarily Telit) (10+ years)

Patents: advanced skills in conceptualization, drafting of disclosures, claims strategies and prosecution (successful prosecution with USPTO on several patent issues and new ones pending)

PATENTS

System for authenticating and authorizing access to and accounting for wireless access vehicular environment consumption by client devices https://patents.google.com/patent/US20180004933A1/en

A system and method are disclosed for authenticating and authorizing access to and accounting for consumption of bandwidth for IPv6 connectivity to the Internet over Wireless Access Vehicular Environment (WAVE) service channels by client devices using an Authentication, Authorization and Accounting (AAA) server. The AAAserver authenticates and authorizes client devices to access WAVE service channels, and accounts for bandwidth consumption by the client devices using WAVE service channels to access the Internet. The AAA server enables an RSU infrastructure operator to quantify wireless bandwidth consumption by in-vehicle devices using the WAVE Service Channels, on a per-device basis.

System and Method for Providing Mobile Automotive Telemetry (US 6,263,268) http://www.google.com/patents/US6263268 July 2001

A mobile automotive telemetry system for installation on-board a vehicle, includes: (i) diagnostic structure for monitoring operational functions of the vehicle and generating operational information; (ii) a memory for storing the generated operational information; and (iii) a server, in communication with the diagnostic structure and the memory. The server includes: (a) structure to receive a request from a remote client for the generated operational information; (b) structure to retrieve the generated operational information from the memory; and (c) structure to transmit the generated operational information to the remote client.

Automotive telemetry protocol (US 7,593,999) https://www.google.com/patents/US7593999 September 2009

Disclosed is a method of conveying vehicle operation data from a vehicle to a remote monitoring recipient, comprising the steps of establishing a data link between the vehicle and the remote monitoring recipient; collecting vehicle operation data from data sources in the vehicle; packaging the vehicle operation data in a data packet using protocol derived from SNMP; and conveying the data packet over the data link.

Automotive telemetry protocol (US 8,560,609) https://www.google.ca/patents/US8560609 October 2013

Continuation of previous patents.

Claims methods for vehicle "neighbour discovery" and collision-avoidance equivalent to vehicle ad-hoc networking based on IEEE 802.11

Vehicle communications via wireless access vehicular environment (US 9,503,968)

https://www.google.com/patents/US9503968 November 2016

This patent application was written in 2013 in order to expand my portfolio in the area of DSRC (Dedication Short-Range Communications), given the imminent USDOT mandate of DSRC V2V (vehicle-to-vehicle) technology for new manufactured vehicles in the U.S. The disclosure focuses on strategic applications, based on integration of Smartphones with DSRC OBUs (On-board units), that are expected to become de facto requirements in all vehicles. Examples of the wide array of applications are: (1)Use and digital authentication of Smartphone as HMI (Human Machine Interface) for V2V safety warnings (2)Smartphone-resident trilateration of mobile geo-position using RSSI (received signal strength indicator) from multiple DSRC roadside units broadcasts. US 9503968 is the first in a series of 4 anticipated patents derived from the original filing.

Automotive Telemetry Protocol (US 9,633,562) https://www.google.com/patents/US9633562 April 2017

Continuation of US 8560609. Claims mobile and stationary nodes capable of functionality equivalent to IEEE 802.11p-enabled On-board units (OBUs) and Roadside Units (RSUs), whereby mobile nodes (OBUs) broadcast messages functionally equivalent to DSRC Basic Safety Messages (BSMs) and stationary nodes (RSUs) broadcast messages functionally equivalent to WAVE Service Advertisements (WSAs). Also claimed are service advertisements by stationary nodes, relative to specific use cases, most significantly signalized traffic light information (i.e. Signal Phase and Timing or SPaT) and Electronic Tolling. The claim set also covers the concept of bi-directional exchange enabling one vehicle to alert a second vehicle of a pending driving maneuver (e.g. when a turn indicator is on) and to receive an acknowledgement from the second vehicle.

PUBLICATIONS

OCCV FCC 13-49 Comment Letter with Attachment https://www.fcc.gov/ecfs/ July 2016

Response to FCC Public Notice of June 1, 2016 regarding revision o Part 15 of the FCC rules to permit Unlicensed National Information Infrastructure (U-NII) devices in the 5 GHz band, Submitted by the Oakland County Connected Vehicle Task Force and co-signed by several automotive Tier 1 suppliers and Director of Michigan Department of Transportation. This document challenges the various proposals being considered by the FCC to allow unlicensed (WiFi) devices to share the DSRC band for Intelligent Transportation. The idea of creating such a document and its initial draft was the work of Martin Nathanson.

Smart Intersections: Paving the Way for a National CAV Deployment

Appendix C:

Glossary

List of terms used in the Smart Intersections Project proposal.

AAA	Authentication, Authorization, and accounting
AAATA	Ann Arbor Area Transit Authority
AACVTE	Ann Arbor Connected Vehicle Test Environment
AASHTO	American Association of State Highway Transportation Officials
ASD	Aftermarket Safety Device
AV	Automated Vehicles
AWS	Amazon Web Services
BCA	Benefit Cost Analysis
BSM	Basic Safety Message
CAMP	Crash Avoidance Metrics Partnership
CAV	Connected/Automated Vehicle
CCAT	Center for Connected and Automated Transportation
CDMA	Code Division Multiple Access
CPM	Collective Perception Message
CSW	Curve Speed Warning
CV	Connected Vehicle
C-V2X	Cellular Vehicle to Everything
CVCP	Connected Vehicle Co-Processor
DBB	Design-Bid-Build
DBFOM	Design-Build-Finance-Operate-Maintain
DMP	Data Management Plan
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
EEBL	Electronic Emergency Brake Light
EVA	Emergency Vehicle Approach
EVP	Emergency Vehicle Preemption
EVTA	Equipped Vehicle Trajectory Awareness

FCC	Federal Communications Commission
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
FIFO	First-in-first-out
FOT	Field Operational Test
FSP	Freight Signal Priority
GB	Gigabyte
GPS	Global Positioning System
HAWK	High-intensity Activated crosswalk beacon
HMI	Human-Machine Interface
HVA	Huron Valley Ambulance
IEEE	Institute of Electrical and Electronics Engineers
IMA	Intersection Movement Assist
IOO	Infrastructure Owner Operator
IRB	Internal Review Board
I-SIG	Intelligent Signal Control
IT	Information Technology
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
IVBSS	Intelligent Vehicle Based Safety Systems
JPO-ITS	Joint Program Office – Intelligent Transportation Systems
JTRP	Joint Transportation Research Program
LTE	Long Term Evolution
MAP	Map (formerly Geometric Intersection Description)
MDOT	Michigan Department of Transportation
MMITSS	Multi-Modal Intelligent Traffic Signal System
MTL	Michigan Traffic Laboratory
NPRM	Notice of Proposed Rule Making

NR	New Radio
NTCIP	National Transportation Communications for Intelligent Transportation System Protocol
NTSA	National Traffic Safety Administration
OBU	On-board Unit
ORSP	Office of Research and Sponsored Projects
OTA	Over-the-Air
P3M	P3Mobility
PATH	Partners for Advanced Transportation Technology
PCAP	Packet Capture
PI	Principle Investigator
PII	Personally Identifiable Information
PMBOK	Program Management Book of Knowledge
PMP	Program Management Professional
POS	Point of Service
PSM	Pedestrian Safety Message
PVD	Probe Vehicle Data
RASIC	Responsible, Approve, Support, Inform, Consult
RDCW	Road Departure Crash Warning
RDS	Radio Data System
RLVW	Red Light Violation Warning
RRFB	Rapid Rectangular Flashing Beacons
RSU	Roadside Unit
RTCM	Differential GPS correction
S3	Simple Storage Service (Amazon)
SAE	Society of Automotive Engineers
SCMS	Security Credential Management System
SCOOT	Split Cycle Offset Optimization Technique
SD	Secure Digital

SDSM	Sensor Data Sharing Message
SDSM	Sensor Data Sharing Message
SOW	Statement of Work
SPaT	Signal Phase and Timing
SPMD	Safety Pilot Model Deployment
TB	Terabyte
T&M	Time and Material
TIM	Traveler Information Message
TSP	Transit Signal Priority
TV	Television
UBI	Usage-based insurance
UM	University of Michigan
UMTRI	University of Michigan Transportation Research Institute
USDOT	United States Department of Transportation
UTC	University Transportation Center
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VAD	Vehicle Awareness Device
VRU	Vulnerable Road Users
WSA	Wave Service Announcement

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Subaward/Subcontract No. _____

Final Invention Statement and Certification *(For Grant or Award)*	Prime Grant / Award No.

A. We hereby certify that, to the best of our knowledge and belief, all inventions are listed below which were conceived and/or first actually reduced to practice during the course of work under the above-referenced grant or award for the period

_____ through _____

original effective date *date of termination*

B. Inventions (Note: If no inventions have been made under the grant or award, insert the word *"NONE"* under Title below.)

NAME OF INVENTOR	TITLE OF INVENTION	DATE REPORTED TO UMich
(Use continuation sheet if necessary)		

C. Signature -This block ***must*** be signed by an official authorized to sign on behalf of the institution.

Title		Name and Mailing Address of Institution
Typed Name		
Signature	Date	

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PROPERTY CLEARANCE FORM

Reference: Research Subaward/Subcontract # _____ from the University of Michigan.

The following information is required for Property Clearance on the above referenced Subaward/Subcontract:

1) There was ☐ was not ☐ fabricated equipment of a permanent and useful nature generated under this agreement. If so, describe briefly:

_____

_____

_____

2) There was ☐ was not ☐ residual inventory of unused supplied and other expendable property exceeding $5,000 in total aggregate value remaining upon termination or completion of the project. If so, describe briefly:

_____

_____

_____

3) List any and all items of equipment acquired under this Subaward/Subcontract:

Equipment	Manufacturer's Name & Model #	Date Acquired	Purchase Price	Serial #

Subrecipient/Subcontractor: _____

AUTHORIZED SIGNATURE: _____

TITLE: _____ DATE: _____