ENRICH

EUROPEAN NETWORK OF RESEARCH AND INNOVATION CENTRES AND HUBS, USA

US Research Handbook on Transportation & Connected and Automated Driving

GAC SBDC FOX Small Business Development Center TEMPLE UNIVERSITY DLR Project Management spi Sociedade Portuguesa de Inovação RCISD NCURA Supporting Research

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Executive Summary

This research handbook is a product of ENRICH in the USA, which is a European Network of Research and Innovation Centers and Hubs. Promoted by the European Commission (EC) through Horizon 2020, ENRICH in the USA acts as a central contact point for European research and innovation actors seeking to grow and reinforce collaboration across the Atlantic. The mission of the Network is to provide standardized as well as various tailor-made, research & innovation internationalization support services to European researchers and innovators, to accelerate access to the United States (US) market and maximize chances of success.

The Research Handbook on US R&D Related to Transportation – Connected and Automated Driving (C&AD) provides an assessment of the United States (US) research community landscape and aims to support research and innovation cooperation between the European Union (EU) and the US. C&AD is a leading research area in the US and in the EU. In fact, only in 2019 there were over 1400 self-driving vehicles are now in testing by 80+ companies across 36 states in the US[1]. Therefore the US and EU research community are highly committed to developing R&D activities in this field[2] and there are significant opportunities to collaborate on those activities.

The Research Handbook identifies US key university research groups, industry-university research centers and industry clusters, as well as some of the main research networks, professional associations and conferences/events in the field of C&AD. Furthermore, the Research handbook identifies potential approaches to develop collaborative projects with the US community in the field of C&AD and assesses the opportunity for EU researchers to participate in US funding programs related to C&AD R&D. Therefore, this research handbook aims to be an effective source to gain knowledge on the US C&AD research community and possible first contacts for initial approaches to establishing collaborative activities.

[1] https://techcrunch.com/2019/06/11/over-1400-self-driving-vehicles-are-now-in-testing-by-80-companies-across-the-u-s/

[2] https://ec.europa.eu/docsroom/documents/24402/attachments/1/translations/en/renditions/native

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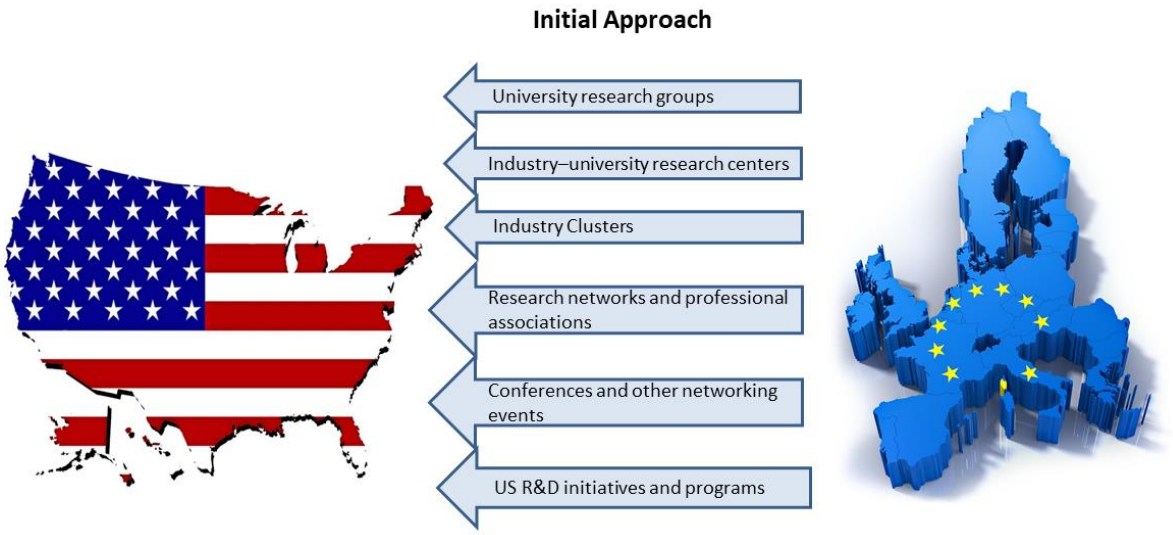

Figure 1 - Initial Approaches to Establishing Collaborative R&D Activities

The EU and the US are key partners in R&D and innovation[3,4]. The US is the EU's main partner in scientific publications, with nearly one tenth of European scientific publications having participation from US authors[5]. R&D and innovation are key components of the EU and US smart growth strategies. Therefore, the EU and the US have achieved many significant scientific innovations due to the quality of the research developed by their universities, research centers and industry clusters in strategic research areas, such as C&AD[6].

R&D and innovation within the transportation sector have led to incremental progress in safety and mobility. It is important to distinguish C&AD from Connected and Automated Vehicles (C&AV). C&AD refers to a set of systems that allow the vehicles to travel without human operation; while C&AV refers to the technologies, procedures or characteristics of the vehicles[7, 8]. C&AV are considered to be the future of mobility, which is encouraging scientists, academics, and other researchers to focus their research activities in this emerging area. C&AV are expected to reshape the future of the mobility systems by reducing accidents, generating environmental benefits and improving personal mobility. Thus, C&AD research, which includes research directly related to C&AV, requires a multidisciplinary approach, as well as a joint effort from researchers of different areas.

[3] https://www.degruyter.com/downloadpdf/j/ergo.2013.8.issue-1/ergo-2013-0002/ergo-2013-0002.pdf
[4] http://ec.europa.eu/research/iscp/index.cfm?amp;pg=usa
[5] https://www.degruyter.com/downloadpdf/j/ergo.2013.8.issue-1/ergo-2013-0002/ergo-2013-0002.pdf
[6] http://www.euussciencetechnology.eu/assets/content/BILATUSA4.0%20-USFunding%20Opportunities%20for%20EU%20Researchers.pdf
[7] http://www.cargroup.org/wp-content/uploads/2017/03/Planning-for-Connected-and-Automated-Vehicles-Report.pdf
[8] https://ec.europa.eu/docsroom/documents/24402/attachments/1/translations/en/renditions/native

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Currently, the US research community is highly committed to conducting C&AD R&D activities. Several leading universities have established research groups focused on thematic research areas related to C&AD and developed important cross-collaborative partnerships with key industry players to advance innovative technologies in this area. By ensuring cutting edge research in C&AD, the US is creating an important opportunity to foster knowledge exchange between the EU-US research communities. Therefore, this research handbook aims to help identify collaborative opportunities in the US in the research area of C&AD.

In order to identify the US key research players in the field of C&AD, the project team conducted extensive desk research based on literature review and document analysis. Therefore, this research handbook identifies many US leading actors in the field of C&AD, which is primarily supported by 5 Thematic Research Areas as identified through a literature review: Artificial Intelligence, Big Data, Cyber-Physical Systems, Cybersecurity and Wireless Communication[9,10,11,12,10,13].

Through desk research, this research handbook reveals the US research community encompasses a complex set of different actors that work in concert for the development of C&AD R&D activities. These key actors in the US research landscape are primarily university research groups, industry–university research centers, and industry clusters[14] .

In addition, there is a high degree of spatial concentration of C&AD R&A activities in four main US states: California, Michigan, Ohio, and Pennsylvania. Another 10 states can also be highlighted due to the presence of leading university research groups, industry university research centers, and industry clusters: Alabama, Arizona, Colorado, Georgia, Indiana, Kentucky, Massachusetts, Texas, Utah and Virginia.

University research groups

The US is home to some of the main university research groups in the field of C&AD. Since C&AD is a multidisciplinary topic that comprises knowledge from different research areas, this research handbook identifies 16 university research groups based on the five Thematic Research Areas related to C&AD.

The 16 university research groups identified in this research handbook are categorized by university. Thus, this research handbook also highlights 10 leading universities in the field of C&AD, such as Carnegie Mellon University and Georgia Institute of Technology, which have more than one research

[9]http://stevens.usc.edu/files/2016/09/USC-Stevens-Connected-Cars-Autonomous-Driving-Overview-September-2016.pdf
[10] http://leempo.com/wp-content/uploads/2017/03/M09.pdf
[11] http://dl.acm.org/citation.cfm?id=2994165
[12] http://ieeexplore.ieee.org/abstract/document/7526648/
[13] https://karambasecurity.com/static/pdf/Autonomous-Automotive-Cybersecurity-Report.pdf
[14] https://karambasecurity.com/static/pdf/Autonomous-Automotive-Cybersecurity-Report.pdf

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group that conducts R&D activities directly in support of C&AD. Moreover, these research groups are composed of researchers from the field of transportation or from the five Thematic Research Areas related to C&AD.

Industry–university research centers

As detailed within this research handbook, the automotive industry is highly focused on fostering C&AD research since there is a large need for breakthrough innovations in this industry. In the US, the establishment of industry–university research centers has mutually benefited research institutions and industrial partners. Industry–university research centers are based on a multidisciplinary research that creates a powerful node for innovation in the field of C&AD. Therefore, in the US several industry–university research centers have emerged as leading actors in the field of C&AD research.

The research handbook highlights 2 different types of industry–university research centers: research centers that have a strong direct collaboration with universities, and primarily industry research centers with a loose connection with university researchers. Based on these two types, 11 industry–university research centers that bring together university researchers and companies are highlighted by the research handbook.

Industry clusters

The assessment of the US research community reveals that industry clusters play a key role in R&D activities related to C&AD. Industry clusters act as a bridge between academic research and the specific needs of the automotive industry sector.

Based on the US Cluster Mapping Project[15], a national economic development initiative led by Harvard Business School and with the support of the US Department of Commerce, Economic Development Administration, the research handbook identifies five industry clusters that stand out for their R&D activities related to C&AD: Silicon Valley, Michigan Automotive Cluster, NW 33 Automotive Cluster, Massachusetts Robotics Cluster, and Cluster for Unmanned Vehicles and Robotics (CUVR). Among these five industry clusters, Silicon Valley and the Michigan Automotive Cluster can be highlighted due to their exceptional C&AD R&D activities[16,17,18].

Research networks and professional associations

The research handbook reveals that research networks and professional associations play a crucial role in fostering interaction between academia, industry and federal/state entities. In the US, research

[15] http://www.clustermapping.us/
[16] https://www.metrotimes.com/news-hits/archives/2017/04/04/report-says-detroit-is-beating-silicon-valley-in-autonomous-car-research
[17] https://www.theverge.com/2017/4/3/15164336/detroit-vs-silicon-valley-self-driving-car-navigant-ranking
[18] http://www.gaccwest.com/en/industries/information-technology-it/high-tech-cluster/

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networks focused on science and engineering research and education are highly supported by the government. However, since C&AD is a recent research area, there are few US research networks focused on C&AD. On the other hand, many new professional associations are created each year in the US, especially associations focused on the fastest-growing industries, such as C&AD.

The research handbook identifies six research networks and professional associations based on a review of the US conferences and events focused on C&AD, which are one of the main activities of these entities.

Conferences and other networking events

Since C&AD is a fast-growing research field in the US, the number of conferences and other networking events focused on C&AD research related fields has been increasing. The research handbook identifies 10 of the main conferences and other networking events focused on C&AD based on an extensive literature review and a review of the conferences sponsored by recognized professional associations in the C&AD field.

US R&D initiatives and programs

As explained by the research handbook, the US R&D funding system is highly decentralized and comprises several actors, such as agencies of federal and state governments, universities, the private sector and non-profit organizations. In the US, the research conducted by universities and research centers is highly supported by federal and state grants that prioritize research areas, which can lead to technological breakthroughs, such as C&AD.

Federal agencies such as the National Science Foundation (NSF), the Department of Defense (DOD) and the Department of Transportation (DOT) have developed several initiatives to support research in the field of C&AD; while state agencies such as Michigan Department of Transportation (MDOT) and Colorado Department of Transportation (CDOT) have identified C&AD as a key research area. Therefore, the NSF supports cooperative research between universities and industry in the field of C&AD through research programs, such as the Smart and Autonomous Systems (S&AS) program. State programs, such as the Florida Automated Vehicles (FAV) program, are also designed to support specific regional research in C&AD. In the US system, many other support schemes of C&AD research are available through federal and state agencies.

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ENRICH in the USA Summary

ENRICH is the European Network of Research and Innovation Centers and Hubs. Started in April 2017, ENRICH in the USA is a H2020 funded initiative whose mission is to establish a Network of European Research and Innovation Centers and Hubs throughout the United States of America. ENRICH in the USA acts as a central contact point for European research and innovation actors seeking to grow, reinforce collaboration, as well as find commercialization paths across the Atlantic.

To do so, ENRICH in the USA is leveraging a network of vetted European and US Partners (entities - including "Ambassadors") and Experts (persons - including "Mentors") as defined below.

The Ambassadors are stakeholders (entities) already supporting R&I actors, and willing to join forces on outreach, funding, programs, and curriculums; this group includes Angel Networks, Venture Capital Firms, Corporate Investors, Corporate Open Innovation Teams, University Incubators, Equity-based accelerators, Clusters, Region, State and Country Government agencies and more. They can also support ENRICH in the USA via sponsorship (cash or in-kind).

Vetted by approved Ambassadors and ENRICH in the USA team, Experts are individuals usually employees of Ambassadors with skills and industry experience. It includes Consultants/Service Providers (i.e., accountants, lawyers, etc.), Angel investors, as well as Mentors. Mentors are volunteering their time to support EU innovators (i.e., review pitch, collaterals, participate in meetings, etc.).

The ENRICH in the USA Network includes the following entities:

- **Three physical ENRICH in the USA Centers:**
  - San Francisco Centre (managed by Temple University SBDC)
  - Boston Centre (managed by Temple University SBDC)
  - Washington, DC Centre (managed by NCURA)

- **Eight Landing Hubs across the US and** plans to expand the ENRICH in the USA Network beyond these first eight Hubs, over four years.

The ENRICH in the USA Network is built on local US experience and strong existing ties between the EU and US, while providing new researcher- and entrepreneur-serving capabilities which address the resource gaps necessary to enable access for all EU Member States and Associated Countries, as well as every state in the US.

A variety of services have been proposed for researchers and entrepreneurs engaged by the Network during the pilot phase, then the Centers' pilot activities have been evaluated to inevitably retain the

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initiative's most successful components to ensure a sustainable plan for ENRICH in the USA in the future.

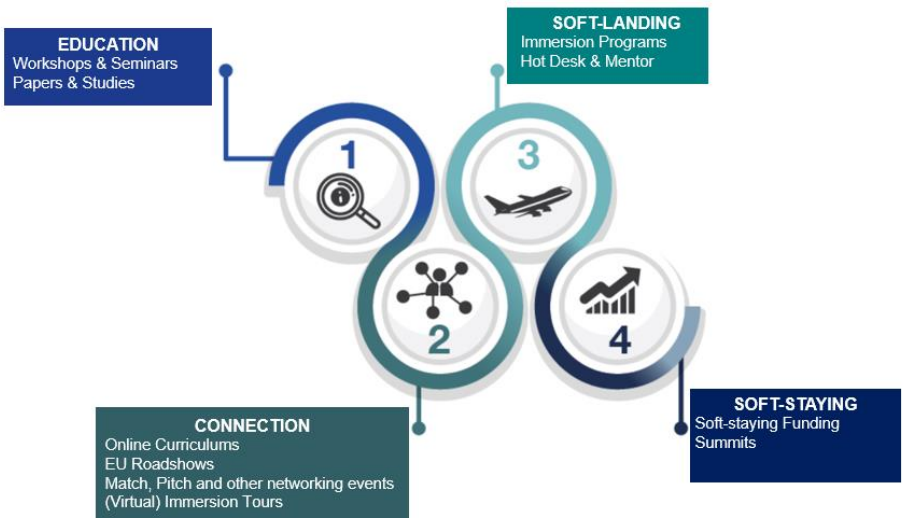
Piloted services targeted various, commercially viable technology maturity levels, both research-oriented and market-oriented and included research connection symposia, business matchmaking opportunities, working visits, immersion weeks, innovation tours to US organizations to explore technology/product partnerships and/or business development middle/long term opportunities, pitching to potential investors, entrepreneurial bootcamps, workspace access, mentorship/advisory, hands-on (pre-acceleration) enrichment programs, and more.

ENRICH in the USA Consortium:

Coordinator: GAC Group (GAC), France

Partners:

> German Aerospace Centre (DLR), Germany
> Temple University SBDC (Temple), USA
> European Business and Innovation Centre Network (EBN), Brussels - Partner in Phase 1 (2017-2020)
> International Business Innovation Association (InBIA), USA - Partner in Phase 1 (2017-2020)
> European American Enterprise Council (EAEC), USA - Partner in Phase 1 (2017-2020)
> INTRASOFT International (INTRA), Luxembourg - Partner in Phase 1 (2017-2020)
> Sociedade Portuguesa de Inovação (SPI), Portugal
> Regional Centre for Information and Scientific Development (RCISD), Hungary
> National Council of University Research Administrators (NCURA), USA



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List of Abbreviations

Table 1 - List of Abbreviations

Abbreviation	Explanation
ACDS	Autonomous Control and Decision Systems Laboratory
ACM	American Center for Mobility
AI	Artificial Intelligence
ARC	Automotive Research Center
ATG	Advanced Technologies Group
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
AUVSI	Association for Unmanned Vehicle Systems International
BLM	Business Leaders for Michigan
CAAR	Center for Advanced Automotive Research
CARS	Center for Automotive Research at Stanford
CAVE	Center for Advanced Vehicle and Extreme Environment Electronics
CDOT	Colorado Department of Transportation
CMU	Carnegie Mellon University
CPS	Cyber-Physical System
CRADA	Cooperative Research and Development Agreements
CSAIL	Computer Science and Artificial Intelligence Laboratory
CUVR	Cluster for Unmanned Vehicles and Robotics
CV	Connected Vehicle

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Abbreviation	Explanation
CVTA	Connected Vehicle Trade Association
C&AD	Connected and Automated Driving
C&AV	Connected and Automated Vehicles
C-UAS	Center for Unmanned Aircraft Systems
DARPA	Defense Advanced Research Projects Agency
DOD	US Department of Defense
DOE	US Department of Energy
DOT	US Department of Transportation
EABO	European-American Business Organization
EAR	Exploratory Advanced Research
EC	European Commission
ECCP	European Cluster Collaboration Platform
EDA	Economic Development Agency
EECS	Electrical Engineering and Computer Sciences
EEMS	Energy Efficient Mobility Systems
EEN	Enterprise Europe Network
ENRICH in the US	European Network of Research and Innovation Centers and Hubs in the US
ESCA	European Secretariat for Cluster Analysis
ESCP-4i	European Strategic Cluster Partnerships
EU	European Union
EV-STS	Efficient Vehicles and Sustainable Transportation Systems
FAV	Florida Automated Vehicles
FCAV	Ford Center for Autonomous Vehicles

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Abbreviation	Explanation
FDOT	Florida Department of Transportation
FFRDC	Federally Funded R&D Centers
FHWA	Federal Highway Administration
FOA	Funding Opportunity Announcement
GDP	Gross Domestic Product
IEEE	Institute of Electrical and Electronics Engineers
IPS	Intelligent Physical Systems
IRIM	Institute for Robotics and Intelligent Machines
ITS	Intelligent Transportation Systems
ITSS	Intelligent Transportation Systems Society
ITS America	Intelligent Transportation Society of America
ITS-CA	Intelligent Transportation Society of California
IUCRC	Industry/University Cooperative Research Centers
JPO	Joint Program Office
MAST	Micro Autonomous Systems and Technology
MDOT	Michigan Department of Transportation
MEDC	Michigan Economic Development Corporation
MIDAS	Michigan Institute for Data Science
MIT	Massachusetts Institute of Technology
MS	Member States
NHTSA	National Highway Traffic Safety Administration
NREC	National Robotics Engineering Center
NSF	National Science Foundation

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Abbreviation	Explanation
NY	New York
ODOT	Ohio Department of Transportation
OISE	Office of International Science and Engineering
OME	Original Equipment Manufacturers
RI	Robust Intelligence
R&D	Research and Development
SAIL	Stanford's Artificial Intelligence Laboratory
SAS	Semi-Autonomous Systems
SCS	School of Computer Science
SME	Small and Medium Enterprises
STI	Science, Technology and Innovation
SVC	Smart Vehicle Concepts Center
S&AS	Smart and Autonomous Systems
TARDEC	Tank Automotive Research Development and Engineering Center
TAS	Transportation as a System
TRI	Toyota Research Institute
UAS	Unmanned Aircraft Systems
UAVRF	Unmanned Aerial vehicles Research Facility
UC	University of California
UM	University of Michigan
UMTRI	University of Michigan Transportation Research Institute
URC	University Research Corridor
US	United States of America

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Abbreviation	Explanation
USCAR	United States Council for Automotive Research
UTC	University Transportation Center
VTO	Vehicle Technologies Office
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Vehicle or Vehicle-to-Infrastructure
XAI	Explainable Artificial Intelligence

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1 Introduction

Context

This research handbook, which has been developed within context of the ENRICH in the USA network[19], aims to provide relevant information on the United States (US) landscape in regard to the Connected and Automated Driving (C&AD) related research community. It provides information on the research community, including key research universities, centers, networks, relevant conferences and events, as well as important industry clusters and initiatives involving the public and private sectors.

The research handbook can be an effective source or tool to gain knowledge on the US C&AD research community and:

- To identify potential approaches to developing collaborative projects with US researchers, research groups and research organizations. The researchers, research groups and centers can be contacted directly to develop a rapport and potential interest in collaborating.
- To identify relevant networks and conferences that can be used as a conduit to meeting potential collaborators.
- To identify and assess the opportunity to participate in US funding programs related to C&AD R&D in order to propose potential project opportunities to US research counterparts.

Therefore, it is the hope of the research handbook authors that the information is useful in assisting European Union (EU) researchers in their efforts to develop stronger ties to the US C&AD research community.

[19] https://www.enrichintheusa.com/

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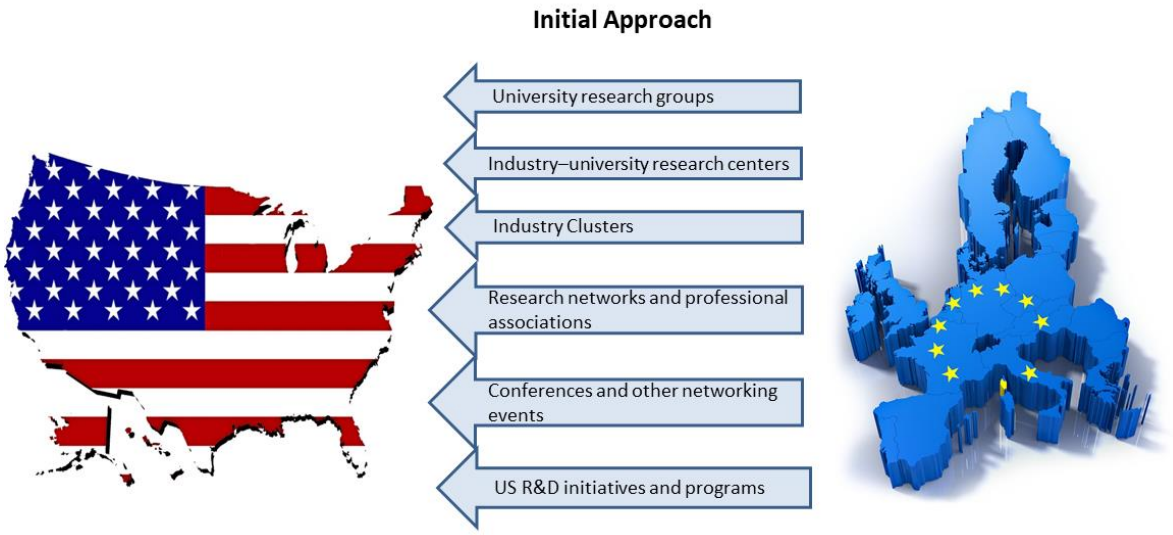

Figure 2 - Initial Approaches to Establishing Collaborative R&D Activities

Transportation sector - Connected and Automated Driving

The European Commission (EC) defines connected and automated driving as a fast-moving key research area that plays a crucial role in the new mobility frontiers (Mobility 4.0)[2021]. The US Department of Transportation's National Highway Traffic Safety Administration (NHTSA) defines automated vehicles as "those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking"[22]. Therefore, automated vehicles are motor vehicles equipped with autonomous technology, which are expected to travel and perceive the environment without direct human operation[23].

The transportation research community has recently changed the term autonomous driving to "Connected and Automated Driving" (C&AD), which represents a wider category of vehicles with advanced information technologies[24]. Therefore, connected driving is the term used to describe technologies that allow vehicles to communicate with each other ("vehicle-to-vehicle", or V2V), and/or with the physical infrastructure ("vehicle-to-infrastructure", or V2I)[25,26]. Furthermore, these

[20] https://ec.europa.eu/digital-single-market/en/news/1st-european-conference-connected-and-automated-driving
[21] http://www.ioeb.at/fileadmin/ioeb/dateiliste/dokumente/Downloads___Links/WS_IV_-_Azmat_Schumayer_-_The_future_has_already_begun_.pdf
[22] https://www.transportation.gov/briefing-room/us-department-transportation-releases-policy-automated-vehicle-development
[23] https://www.law.washington.edu/clinics/technology/reports/autonomousvehicle.pdf
[24] http://www.cargroup.org/wp-content/uploads/2017/03/Planning-for-Connected-and-Automated-Vehicles-Report.pdf
[25] https://energy.gov/sites/prod/files/2015/11/f27/QTR2015-8A-Connected-Automated-Vehicles.pdf
[26] http://www.atkinsglobal.com/~/media/Files/A/Atkins-Corporate/north-america/sectors-documents/highways-and-bridges/library-docs/brochures/CAV_Report-NorthAmerica_v2.pdf

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technologies can improve road safety, avoid collisions, reduce congestion, improve energy efficiency and lead to the development of new models for vehicle ownership [27].

The terms C&AD and C&AV are both use in this research handbook. The term C&AD is used as a research area, while the term C&AV is used to describe specific technologies, procedures or characteristics of the vehicles.

Importance of C&AD to the EU and US

The EU and the US are key partners in R&D. In 1998, the EU and the US signed the Agreement for Scientific and Technological Cooperation, which governs the R&D and innovation cooperation between the EU and the US. This agreement has been renewed four times for a period of five years each time and is now valid until October 2023[28,29]. Both the EC and the US government recognize C&AD as a leading research area and, therefore, have implemented R&D programs to support C&AD research. The EU programs aim to foster further research synergies and activities with leading countries outside Europe, such as the US[30].

The EC recognizes there are important opportunities to use world-wide knowledge to tackle the current challenges related with C&AD research. For instance, the EC has agreed with the US DOT to fund "twin" research projects in the field of C&AD[31].

In the US, C&AD research is strongly encouraged by federal initiatives from the DOT, DOD, and the NFS. Several state initiatives also support C&AD research. Moreover, the NSF is heavily committed to foster C&AD research and, therefore, has supported four related Industry/University Cooperative Research Centers (IUCRCs): Smart Vehicle Concepts[32], Efficient Vehicles and Sustainable Transportation Systems[33], Center for Unmanned Aircraft Systems[34], and Center for Advanced Vehicle and Extreme Environment Electronics[35].

The US automotive private industry and technology companies involved in internet related services also play a key role in C&AD research. Companies like Google, Uber and General Motors have established synergies with universities and research centers to develop important research in the field. Similar to the US, the existing EU projects and programs in the field of transportation often include both private and public funds. Indeed, the EU transportation related projects have a high private-for-

[27] http://autocaat.org/Technologies/Automated_and_Connected_Vehicles/
[28] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Ari0009
[29] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Ari0009
[30] https://ec.europa.eu/docsroom/documents/24402/attachments/1/translations/en/renditions/native
[31] https://circabc.europa.eu/sd/a/40c4104e-5f7d-4cc4-a418-679e72c5fc7e/Road-20160615-WG-pres-EU%20activities%20on%20automated%20vehicles.pdf
[32] http://www.iucrc.org/center/smart-vehicle-concepts
[33] http://www.iucrc.org/center/efficient-vehicles-and-sustainable-transportation-systems
[34] http://www.iucrc.org/center/center-unmanned-aircraft-systems
[35] http://www.iucrc.org/center/center-advanced-vehicle-and-extreme-environment-electronics

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profit entity participation, which proves a growing interest from the private sector in the area of transportation research[36].

The EU private industry is also very interested in C&AD research. Therefore, three European Strategic Cluster Partnerships (ESCP-4i), which are transnational cluster partnerships that develop and implement a joint internationalization strategy and support SME internationalization towards third countries beyond Europe[37], are focused on transportation, representing over 1800 SMEs[38]. In fact, two ESCP-4i's (MobiGoIn[39] and PERES[40]) targeted the US specifically. Moreover, more than 90 clusters registered with the European Cluster Collaboration Platform are related to the automotive sector[41].

The US is the largest R&D performer in the world, as it was the leading country/region in terms of R&D expenditure. In 2018, taking into consideration all R&D fields, the US had a R&D intensity of 2.82% and the EU had a R&D intensity of 2.19%[42]. The US also leads in C&AD innovation, particularly in terms of technology, with over 150 companies intensively working on the technology headquartered in the country[43]. The collaboration between the EU and the US in the domain of C&AD R&D activities is considered as highly strategic. While the US federal investment in R&D has remained fairly constant since 2010, the industry investments in R&D have increased, especially in fast-growing sectors, such as C&AD. The US is one of the global leaders in terms of C&AD R&D activities and, therefore, it is a privileged partner in the field of C&AD for the EU Member States[44, 45].

It should be highlighted that 8 organisations from the USA participated in 9 H2020 projects funded under topics related to transport & connected and automated driving (details of the EU-US collaborative projects are contained in Annex 3: Summary of the collaborative EU-USA H2020 projects).

Thematic Research Areas related to Connected and Automated Driving

C&AD includes a wide range of technologies, infrastructure and capabilities in different areas. Therefore, C&AD should be analyzed as the result of several developments within a broader research context. Automated driving is an active area of research and has numerous challenging applications

[36] https://ec.europa.eu/docsroom/documents/24402/attachments/1/translations/en/renditions/native
[37] https://www.clustercollaboration.eu/eu-cluster-partnerships
[38] https://www.clustercollaboration.eu/escp-list?combine=&field_escp_category_value=All&name_list=All&field_escp_sectorial_industries_tid=45&technology_field_id
[39] https://www.clustercollaboration.eu/escp-profiles/mobigoln
[40] https://www.clustercollaboration.eu/escp-profiles/peres
[41] https://www.clustercollaboration.eu/cluster-list
[42] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20201127-1
[43] https://assets.kpmg/content/dam/kpmg/tw/pdf/2018/03/KPMG-Autonomous-Vehicle-Readiness-Index.pdf
[44] http://www.euussciencetechnology.eu/assets/content/documents/annex_roadmaps_oct-2016.pdf
[45] http://graham.umich.edu/media/files/LC-IA-ACE-Roadmap-Expert-Forecast-Underwood.pdf

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that require research from other areas. According to several studies, the main thematic research areas related to C&AD are the following[46,47,48,49,50]:

- **Artificial intelligence (AI):** AI is a division of computer science that deals with the simulation of intelligent behavior in computers, i.e. the capability of a machine to imitate intelligent human behavior[51]. AI developments in sensor quality and computing power play a major role in the context of C&AD[52,53].

- **Big Data:** Big data analysis is the use of advanced analytic methods against diverse data sets that include different types and sizes of data[54]. C&AD involves collecting and analyzing big amounts of sensor and traffic data, which is crucial to enable intelligent traffic routing to avoid congestions[55].

- **Cyber-physical systems (CPSs):** CPSs are integrations of computation, networking, and physical processes[56]. In this context of C&AD, networked embedded real-time systems are crucial to monitor the entire execution chain and ensure safety[57].

- **Cybersecurity:** Cybersecurity is the body of technologies used to protect the integrity of networks, programs and data from attack, damage, or unauthorized access[58]. In the context of C&AD, cybersecurity involves protecting the integrity of the data that is communicated between the vehicles; preventing unauthorized access that can result in the highjack of the control system and protection of the personal data that is stored in the system[59,60].

- **Wireless Communication:** Wireless communication includes the procedures and forms of connecting and communicating between different devices using a wireless signal[61]. The developments in wireless communication will have and important impact in C&AV since big

[46] http://stevens.usc.edu/files/2016/09/USC-Stevens-Connected-Cars-Autonomous-Driving-Overview-September-2016.pdf
[47] http://leempo.com/wp-content/uploads/2017/03/M09.pdf
[48] http://dl.acm.org/citation.cfm?id=2994165
[49] http://ieeexplore.ieee.org/abstract/document/7526648/
[50] https://karambasecurity.com/static/pdf/Autonomous-Automotive-Cybersecurity-Report.pdf
[51] https://www.merriam-webster.com/dictionary/artificial%20intelligence
[52] https://www.ft.com/content/36933cfc-620c-11e7-91a7-502f7ee26895
[53] https://www.forbes.com/sites/currentaccounts/2017/03/09/the-ai-debate-critical-to-the-future-of-autonomous-vehicles/#3eb270297179
[54] https://www.ibm.com/analytics/us/en/technology/hadoop/big-data-analytics/
[55] http://stevens.usc.edu/files/2016/09/USC-Stevens-Connected-Cars-Autonomous-Driving-Overview-September-2016.pdf
[56] http://cyberphysicalsystems.org/
[57] http://ieeexplore.ieee.org/document/6603997/
[58] https://www.paloaltonetworks.com/cyberpedia/what-is-cyber-security
[59] http://stevens.usc.edu/files/2016/09/USC-Stevens-Connected-Cars-Autonomous-Driving-Overview-September-2016.pdf
[60] https://www.lexisnexis.com/communities/corporatecounselnewsletter/b/newsletter/archive/2017/03/07/self-driving-cars-are-barreling-down-the-innovation-highway.aspx
[61] https://www.techopedia.com/definition/10062/wireless-communications

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amounts of data and information will be shared between vehicles, mobile devices, infrastructures, and other electronic appliances wirelessly[62].

Although there are other areas that may also be of high interest to the European research and industry communities, the scope of this report is based on its objective which is to demonstrate various avenues EU researchers and SMEs can take to approach the US research community related to the above defined areas. A similar approach could be taken for many related area of interest.

[62] http://stevens.usc.edu/files/2016/09/USC-Stevens-Connected-Cars-Autonomous-Driving-Overview-September-2016.pdf

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2 US research community landscape

The US is the world-leading country in both terms of public and private R&D investment[63,64]. In 2019, the country's Gross domestic spending on R&D was estimated to $656 billion (nearly €541 billion), which represents about 3.1% of its Gross Domestic Product (GDP), and more importantly, accounted for over a third of the global R&D investment[65]. The R&D programs are mainly supported by industry ($463 billion, nearly €382 billion), the Federal Government ($138 billion, nearly €114 billion), Academia ($22 billion, nearly €18 billion), and non-profits organizations ($27 billion, nearly €23 billion)[66].

The US research landscape is comprised of world leading universities, research centers, research networks and industry clusters that are funded primarily by an extensive network of federal and state funding initiatives and industry endowments[67]. The US research community encompasses a complex set of different actors that receive support through a large number of agencies, such as the DOD, DOT and NSF. The key actors in the US research landscape are university research groups, industry–university research centers and industry clusters, which play different but complementary roles in the R&D field[68].

As stated earlier, C&AD is a multidisciplinary area that implies a wide range of cutting edge technologies and knowledge from related research areas. Therefore, in the US, the C&AD research community landscape is highly complex and requires an intensive cooperation between academia and industry. Considering this complexity, the research handbook focuses on many of the main actors and funding agencies related to AI, Big Data, CPSs, Cybersecurity and Wireless Communication[69].

Moreover, the map below shows a high degree of spatial concentration of C&AD R&A activities in four main US states: California, Michigan, Ohio and Pennsylvania. In addition, another 10 states can also be highlighted due to the presence of leading university research groups, industry-university research centers or industry clusters: Alabama, Arizona, Colorado, Georgia, Indiana, Kentucky, Massachusetts, Texas, Utah and Virginia.

Within the states of California, Michigan, Ohio and Pennsylvania, the C&AD R&D activities are also very concentrated in some cities. In California, there is a high level of C&AD R&D activities in Silicon Valley, which includes the surround areas of Stanford University. In Michigan, the city of Detroit is home to some of the leading university research groups, industry-university research centers and industry

[63] https://www.aip.org/fyi/2016/us-rd-spending-all-time-high-federal-share-reaches-record-low
[64] https://www.iriweb.org/sites/default/files/2016GlobalR%26DFundingForecast_2.pdf
[65] http://digital.rdmag.com/researchanddevelopment/2018_global_r_d_funding_forecast?pg=4#pg4
[66] https://ncses.nsf.gov/pubs/nsf21324
[67] http://www.rcuk.ac.uk/international/offices/us/research-landscape-in-the-usa/
[68] https://itif.org/publications/2014/06/30/understanding-us-national-innovation-system
[69] https://www.rand.org/topics/autonomous-vehicles.html

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clusters. In Ohio, there is also a high concentration of C&AD R&D activities in Columbus; while in Pennsylvania there is a concentration in Pittsburg.

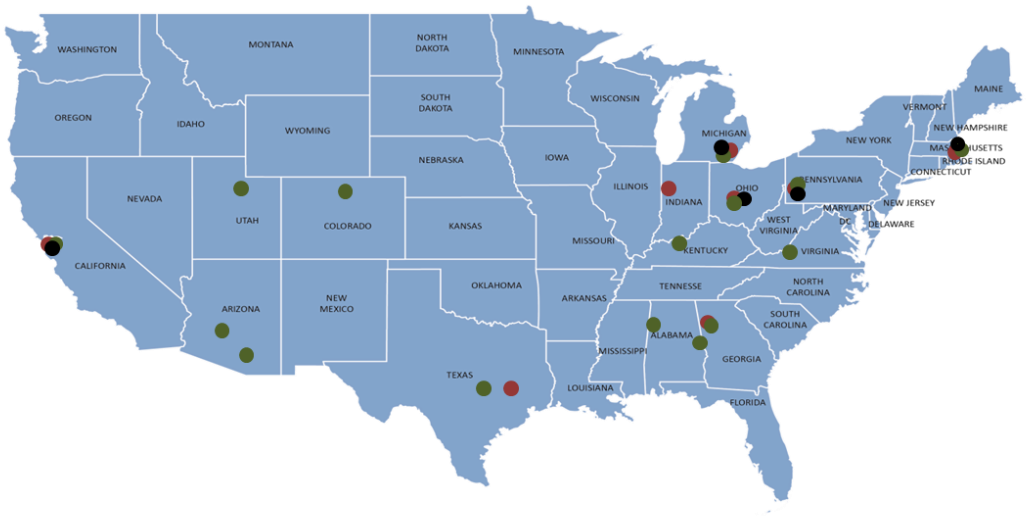

Figure 3 - US Geographic Distribution of University Research Groups, Industry-University Research Centers and Industry Clusters Focused on R&D Activities in the Field of C&AD

University research groups

Carnegie Mellon University (CMU), Pittsburgh, Pennsylvania
Georgia Institute of Technology, Atlanta, Georgia
Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts
Ohio State University, Columbus, Ohio
Purdue University, West Lafayette, Indiana
Stanford University, Stanford, California
Texas A&M, University, College Station, Texas
University of California, Berkeley, California
University of Michigan, Ann Arbor, Michigan

Industry–university research centers

Automotive Research Center (ARC), Ann Arbor, Michigan
Center for Advanced Automotive Research (CAAR), Blacksburg, Virginia
Center for Advanced Vehicle and Extreme Environment Electronics (CAVE), Auburn, Alabama
Center for Unmanned Aircraft Systems (C-UAS), Provo, Utah; Atlanta, Georgia; Boulder, Colorado; Ann Arbor, Michigan; Blacksburg, Virginia
Center for Automotive Research at Stanford (CARS), Stanford, California
Efficient Vehicles and Sustainable Transportation Systems (EV-STS), Tuscaloosa, Alabama; Tempe, Arizona; Louisville, Kentucky; Austin Texas
Ford Research and Innovation Center Palo Alto, California
Smart Vehicle Concepts Center (SVC), Columbus, Ohio
Toyota-CSAIL Joint Research Center,

Industry Clusters

Silicon Valley, California
Michigan Automotive Cluster, Detroit, Michigan
NW 33 Automotive Cluster, Columbus, Ohio
Massachusetts Robotics Cluster, Boston, Massachusetts
Cluster for Unmanned Vehicles and Robotics, Pittsburgh, Pennsylvania

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University research groups ●

Industry–university research centers ●
Cambridge, Massachusetts
Uber Advanced Technologies Group (ATG), Pittsburgh, Pennsylvania
UM & Ford Center for Autonomous Vehicles (FCAV), Ann Arbor, Michigan

Industry Clusters ●

2.1. University research groups

University research groups are comprised of researchers who share common and complimentary research interests in leading areas and have similar needs with respect to research infrastructure[70,71]. With respect to this research handbook, a university research group is either a research center or institute housed at a university campus, or a division, department or laboratory of a university.

The university research groups identified in this section have been selected based on extensive literature review. The identified research groups are focused on at least one of the five main thematic research areas: AI, Big Data, CPSs, Cybersecurity and Wireless Communication.

In addition, the research groups are categorized by university as C&AD is a multidisciplinary area comprised of knowledge from different research areas. Therefore, universities can have more than one research group focused on the development of technologies and infrastructure related to C&AD.

World leading universities in the field of C&AD, such as Carnegie Mellon University (CMU) and Georgia Institute of Technology, have more than one research group that conducts R&D activities in this area. In this context, the research conducted by the identified groups can be specific to the field of transportation (e.g. University of Michigan Transportation Research Institute); or can be broader and applied to different areas (e.g. Stanford's Artificial Intelligence Laboratory). Most of the identified research groups are focused on R&D activities in the fields of AI and CPSs, which reveals the importance of conducting specific research in robotics, unmanned systems and control systems to develop advanced C&AD technologies.

[70] http://www.sussex.ac.uk/research/about/groups/
[71] https://www.wits.ac.za/health/research/research-entities/definition-of-an-entity/

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Table 2 - Sample of University Research Groups

Carnegie Mellon University (CMU)

Research group	Research coordinator (RC) name	RC email address	Relevant research areas	Internet link
National Robotics Engineering Center (NREC)	Dr. Herman Herman	contact@nrec.ri.cmu.edu	CPSs • Development of control systems for C&AV	www.nrec.ri.cmu.edu
Computer Science Department – Carnegie Mellon University	Professor Srinivasan Seshan (Head of Computer Science Depratment)	srini@cs.cmu.edu	AI and CPSs • Development of C&AV navigation systems	https://csd.cmu.edu/about-computer-science-department
University Transportation Center (UTC)	Professor Raj Rajkumar	rajkumar@cmu.edu	CPSs • Research on sensors for C&AV Wireless communication • Research on systems for wireless communications for C&AV (also named, inter-vehicle communications)	http://www.cmu.edu/homepage/computing/2012/winter/transportation-research.shtml

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Georgia Institute of Technology

Research group	Research coordinator (RC) name	RC email address	Relevant research areas	Internet link
Institute for Robotics and Intelligent Machines (IRIM)	Professor Evangelos A. Theodorou	evangelos.theodorou@ae.gatech.edu	AI, Big Data and CPSs • Development of machine learning algorithms for statistical inference, learning and control	http://www.robotics.gatech.edu/about
Autonomous Control and Decision Systems Laboratory (ACDS), Daniel Guggenheim School of Aerospace Engineering				http://acds-lab.gatech.edu/
Unmanned Aerial vehicles Research Facility (UAVRF), Daniel Guggenheim School of Aerospace Engineering	Professor Eric N. Johnson	eric.johnson@ae.gatech.edu	AI, CPSs and Wireless Communication • Research on guidance, navigation, and control of unmanned aerial vehicles	http://www.uavrf.gatech.edu/

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Center for Transportation Operations and Safety, School of Civil and Environmental Engineering	Professor Michael Hunter	michael.hunter@ce.gatech.educ	CPSs • Management and operation of our future roadways	http://transportation.ce.gatech.edu/

Massachusetts Institute of Technology (MIT)

Research group	Research coordinator (RC) name	RC email address	Relevant research areas	Internet link
Center for Biological & Computational Learning (CBCL)/ Poggio Lab , Department of Brain and Cognitive Sciences	Professor Tomaso Poggio	dlees@mit.edu[72]	AI • Research on how intelligence is created by the brain and how it may be replicated in machines.	http://poggio-lab.mit.edu/, https://cbmm.mit.edu/

[72]This email address belongs to Diana Lees who is responsible for the external communication.

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Robotic Mobility Group	Dr. Karl Iagnemma	kdi@mit.edu	AI and CPSs • Research and development of systems to control A&CV	http://web.mit.edu/mobility/research/index.html

Ohio State University

Research group	Research coordinator (RC) name	RC email address	Relevant research areas	Internet link
Department of Electrical and Computer Engineering Transportation Research Center (TRC)	Professor Ümit Özgüner	ozguner.1@osu.edu	CPSs • Participation in several autonomous driving challenges including Demo'97 and all the DARPA Grand and Urban Challenges	www.cps-vo.org/node/29572

Purdue University

Research group	Research coordinator (RC) name	RC email address	Relevant research areas	Internet link

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Transportation and Infrastructure Systems group, School of Civil Engineering	Professor Srinivas Peeta	peeta@purdue.edu	AI, Big Data, CPSs and Wireless Communication • Research on smart infrastructures and advanced technologies for C&AV	https://engineering.purdue.edu/~peeta/

Stanford University

Research group	Research coordinator (RC) name	RC email address	Relevant research areas	Internet link
Stanford's Artificial Intelligence Laboratory (SAIL)	Professor Juan Carlos Niebles	jniebles@stanford.edu	AI and CPSs • Research on Artificial Intelligence for the development of technologies for C&AV • Development of a robot vehicles (developed Stanley in 2005, in the context of the DARPA Grand Challenge)	www.ai.stanford.edu/

Texas A&M University

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Research group	Research coordinator (RC) name	RC email address	Relevant research areas	Internet link
Cyberphysical Systems Lab, Computer Engineering & Systems Group, Department of Electrical & Computer Engineering	Professor P. R. Kumar (assistant: Carolyn Warzon)	prk.tamu@gmail.com c-warzon@tamu.edu	AI, CPCs, Cybersecurity and Wireless Communication • Development of CPCs for C&AV to control traffic, to address cybersecurity challenges and to improve wireless communication (V2X)	https://cesg.tamu.edu/faculty/p-r-kumar/convergencelab/

University of California, Berkeley

Research group	Research coordinator (RC) name	RC email address	Relevant research areas	Internet link
Department of Electrical Engineering and Computer Sciences (EECS)	Professor Sanjit Seshia	sseshia@eecs.berkeley.edu	CPSs • Development of improved cyber-physical systems for C&AV (involved in an interdisciplinary project titled VeHICaL – Verified Human Interfaces, Control and Learning for Semi-Autonomous Systems)	www.cps-vo.org/node/29572

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University of Michigan

Research group	Research coordinator (RC) name	RC email address	Relevant research areas	Internet link
Michigan Institute for Data Science (MIDAS)	Professor Pascal Van Hentenryck	pvanhent@umich.edu	Big Data • Big data analysis for reinventing public urban transportation and mobility (involved in the MIDAS Challenge Initiatives program)	https://news.engin.umich.edu/2017/01/midas-grant/
University of Michigan Transportation Research Institute (UMTRI)	Professor Henry Liu	pvanhent@umich.edu	CPSs • Systems for monitoring, modelling, and controlling traffic networks	https://news.engin.umich.edu/2017/01/midas-grant/
	Professor Sam Lauzon and Professor Steve Stachowski	slauzon@umich.edu, smstacho@umich.edu	Cybersecurity • Research on cybersecurity for connected vehicles, focusing on vehicle-to-vehicle or vehicle-to-infrastructure (V2X)	http://www.umtri.umich.edu/our-focus/cybersecurity

Annex 1 presents further examples of research organizations in the thematic research areas related to C&AD that were identified based on desk research, not through the analysis of paper citations.

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2.2. Industry–university research centers

Partnerships between industry and universities are especially important in the field of C&AD due to the need for an interdisciplinary approach and the growing complexity of the technologies required for the development of C&AD. In the US, the development of industry-university research centers is common as a result of universities becoming more entrepreneurial, and industry realizing the potential of academia to fill the need for applied research over the last several decades. This is certainly true for the specific research fields of C&AD[73]. In this context, there are two main types of industry–university research centers considered by this research handbook:

- Research centers that have a strong direct collaboration with universities. Among these centers there are two different types: centers that are developed between a university and a single company (e.g. UM & Ford Center for Autonomous Vehicles) and centers that are established by a university and several companies and other organizations (e.g. NSF sponsored Industry–University Cooperative Research Centers).
- Industry research centers with a loose connection with university researchers (e.g. Ford Research and Innovation Center Palo Alto).

The centers highlighted in this research handbook were selected based on the abovementioned criteria. The identification of the centers was done by desk research, which included an extensive literature review and a review of known federal and state entities that support the establishment of these centers.

Automotive Research Center (ARC)

Research Areas: CPSs

Coordinator: Mr. William Lim, https://me.engin.umich.edu/people/staff[74]

The ARC, a university-based US Army Center of Excellence, aims to advance the technology of high fidelity simulation of military and civilian ground vehicles through the development of new simulation and modeling tools. The center is a key research partner of the US Army Tank Automotive Research, Development and Engineering Center (TARDEC) in Warren, Michigan. This partnership with ARC (University of Michigan) aims at meeting the research needs of the Center's Army sponsors. The ARC has also been establishing several partnerships with other universities, namely with the Wayne State University, Oakland University, the University of Iowa, Clemson University and Virginia Tech.

[73] https://www.rdmag.com/article/2015/04/how-academic-institutions-partner-private-industry

[74] There is no specific link to a page with William Lim profile, but you can contact him for more information at choonhun@umich.edu or 001 734 647 9051.

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http://outreach.umich.edu/programs/automotive-research-center-arc/

Center for Advanced Automotive Research (CAAR)

Research Areas: CPSs and Wireless Communication

Coordinator: Dr. Zac Doerzaph, http://www.vtti.vt.edu/research/caar/index.php[75]

The main objective of the CAAR is to promote research, development and evaluation of future automotive systems. The center, which includes the Advanced Product Test and Evaluation group and the Connected & Advanced Vehicle Systems group, is staffed by a multidisciplinary team of researchers and professionals from Virginia Tech Transportation Institute, who work cooperatively with industry and governmental players. The primary research areas of the center include crash warning/ avoidance/ mitigation, connected vehicles, driver-vehicle interfaces, crash causation, and vehicle automation.

http://www.vtti.vt.edu/research/caar/index.php

Center for Advanced Vehicle and Extreme Environment Electronics (CAVE)

Research Areas: CPSs

Coordinator: Professor Pradeep Lall, http://www.iucrc.org/node/5171

The NSF IUCRC for Advanced Vehicle and Extreme Environment Electronics (CAVE3, also known as CAVE), located at the Auburn University, aims at developing and implementing new technologies for the packaging and manufacturing of electronics. The research and development activities of the center focus on the harsh environment, reliability, prognostics and cost. The CAVE center membership includes Original Equipment Manufacturers (OEMs) as well as their suppliers of components, printed wiring boards, and electronics materials. The center explores the commonality of themes related to electronic systems in the automotive, military, defense, aerospace and space-based applications.

http://www.iucrc.org/center/center-advanced-vehicle-and-extreme-environment-electronics

Center for Unmanned Aircraft Systems (C-UAS)

Research Areas: AI, CPSs and Wireless Communication

Coordinator: Professor Tim McLain, http://www.iucrc.org/node/5528

The main objective of the C-UAS is to investigate and develop new algorithms, architectures, and operational procedures for unmanned aircraft systems. The C-UAS, which brings together industry and university researchers, comprises laboratories located at Brigham Young University, University of

[75]There is no specific link to a page with Zac Doerzaph profile, but you can access more information regarding him by click at his name (in orange) in the link.

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Colorado Boulder, University of Michigan, Georgia Institute of Technology, and Virginia Polytechnic Institute and State University. The research conducted at the center is focused on five main topics: advanced autonomous capabilities for UAS, UAS-based communication networks, multi-agent cooperative control of UAS, human interfaces for UAS, and UAS integration into the National Airspace System.

http://www.iucrc.org/center/center-unmanned-aircraft-systems

Center for Automotive Research at Stanford (CARS)

Research Area: AI and CPSs

Coordinator: Dr. Stephen Zoepf, https://cars.stanford.edu/people/stephen-zoepf

The CARS aims at supporting research and organizing events that bring together students, campus researchers and industry professionals. The CARS is located at the Automotive Innovation Facility, on the Stanford University campus, which is also the location for the Volkswagen Automotive Innovation Lab (often referred to as VAIL), a state-of-the-art vehicle research facility. The center focuses on building the next generation of vehicles, namely A&CD by bringing together academic, industry and government players from the automotive sector.

https://cars.stanford.edu/

Efficient Vehicles and Sustainable Transportation Systems (EV-STS)

Research Areas: CPSs and Wireless Communication

Coordinator: Dr. Glen Prater, http://www.iucrc.org/node/7206

The EV-STS center is a multi-discipline and multi-university research organization, focusing on research to significantly improve the energy efficiency and environmental sustainability of ground vehicles. The center, which has laboratories at the University of Louisville, University of Alabama, Arizona State University and University of Texas at Austin, aims to strengthen the bonding between academia and industry players as well as between the public and private sectors. The center has a research program titled Vehicle Systems Optimization, with the objective of improving the efficiency and sustainability of autonomous vehicles, namely by conducting research on CPSs, 5G communication and sensors.

http://www.iucrc.org/center/efficient-vehicles-and-sustainable-transportation-systems

Ford Research and Innovation Center Palo Alto/ The Ford Greenfields Labs

Research Areas: Big Data, CPSs and Wireless Communication

Director: Priya Rajendran, https://corporate.ford.com/careers/job-profiles/priya-rajendran.html The Ford Greenfields Labs, Palo Alto facility is one of the largest automotive manufacturer research centers in the region. The center, which has been established under the Ford Mobility initiative, aims at accelerating innovation in connectivity, mobility, the customer experience and Big Data analysis for

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the development of new vehicles, namely A&CV. The center is coordinated by the Ford Research and Innovation team, but it benefits from a loose connection with over 300 researchers, engineers and scientists from the Silicon Valley universities ecosystem.

https://corporate.ford.com/operations/locations/silicon-valley.html

Smart Vehicle Concepts Center (SVC)

Research Areas: AI and CPSs

Coordinator: Dr. Marcelo Dapino, http://www.iucrc.org/node/4908

The SVC is focused on research and development of smart structures, next-generation suspension and mounting devices, improved actuators or valves, intelligent sensors, and improved health monitoring and diagnostic systems that could be integrated in the next generation of ground and aerospace vehicles. The center, located at the Ohio State University, supports the US Automotive and Aerospace industries to remain competitive in an increasingly challenging global economy, by providing them technical results and solutions as well as educational and advanced training courses.

http://www.iucrc.org/center/smart-vehicle-concepts

Toyota-CSAIL Joint Research Center

Research Area: CPSs

Coordinator: Professor Daniela Rus, http://danielarus.csail.mit.edu/index.php/contact/

The main objective of the Toyota-CSAIL Joint Research Center is to promote the development of autonomous vehicle technologies that could reduce traffic casualties and prevent vehicle accidents, through the development of advanced decision-making algorithms and systems. This center has been established by an automotive manufacturing company, Toyota, and, the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL).

https://toyota.csail.mit.edu/

UM & Ford Center for Autonomous Vehicles (FCAV)

Research Area: CPSs

Coordinator: Professor Matthew Johnson Roberson, http://droplab.engin.umich.edu/matthew-johnson-roberson

The UM & FCAV Center aims to accelerate autonomous vehicle research, with emphasis on the research of perception, control, and planning for level-4 self-driving cars. Currently, the center is conducting 2 research projects: one focused on an automated method to identify mistakes made by object detectors without ground truth labels; another focused on training machine learning algorithms. The center has been established by the University of Michigan and Ford Motor Company.

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https://fcav.engin.umich.edu/

2.3. Industry clusters

For the purpose of this research handbook, industry clusters are defined as geographic concentrations of businesses of closely-related industries. In the US, the industry clusters have been a catalyst for economic growth for over a century, mostly due to the ability of some leading universities in the country to work cooperatively with industry. The US is embracing the system of a label or guarantee of quality from national programs such as the European Secretariat for Cluster Analysis (ESCA) certification based on a bronze, silver, or gold label[76].

Despite their importance, the cluster organizations in the US are not as institutionalized as in the EU. Nevertheless, there are numerous clusters that are represented by a formal cluster organization and tend to be supported by local Economic Development Agencies (EDA's), whereas some others are part of public and/or private organizations (e.g. Federal Agencies, Industry Associations, etc.) that aim to promote competitiveness and innovation in a particular sector.

The US Cluster Mapping Project, a national economic development initiative led by Harvard Business School and with the support of the US Department of Commerce, Economic Development Administration, aggregates all the country clusters providing valuable insights on business environment, demographics and performance of the clusters[77]. The platform can be considered as a formal US cluster connector, and has been used to identify the most relevant industry clusters for the C&AD industrial sub-sector. Among those clusters, there are five which stand out particularly for their C&AD R&D activities, with the Silicon Valley and Detroit clusters being exceptional cases in this research field[78,79,80].

Silicon Valley, State of California

Silicon Valley is widely recognized as the world largest and most important high tech cluster. The combination of a highly skilled labor force and a high concentration of leading universities and research centers, such as Stanford University, UC Berkeley and UC San Francisco, together with significant access to venture capital, have led Silicon Valley to be considered the high-tech center of the US[81]. Thus, Silicon Valley promotes a very important cooperation and coexistence between large industry

[76]ESCA, Jan 2017. http://cluster-analysis.org/benchmarked-clusters/?country=6a7389f0dba345fab09a30cd321b3d23
[77]http://www.clustermapping.us/
[78]https://www.nytimes.com/2016/12/20/business/silicon-valley-dominating-self-driving-tech-motor-city-says-not-so-fast.html?mcubz=1
[79]https://www.metrotimes.com/news-hits/archives/2017/04/04/report-says-detroit-is-beating-silicon-valley-in-autonomous-car-research
[80]https://www.theverge.com/2017/4/3/15164336/detroit-vs-silicon-valley-self-driving-car-navigant-ranking
[81]http://www.gaccwest.com/en/industries/information-technology-it/high-tech-cluster/

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firms, startups, universities and research centers, which allows the development of cutting edge technologies[82].

Currently, C&AD is the new frontier in Silicon Valley. Silicon Valley is home to some of the world's leading auto industry and tech players, such as Apple, Google, Lyft, Uber, Tesla, Waymo, among others[83]. Hardware, software and data developed in Silicon Valley are crucial for the advancement of C&AD technologies. In fact, Silicon Valley offers a highly innovative environment that allows the cooperation between hardware and software companies, such as Tesla that uses Nvidia chips to control all of its cars[84].

ENRICH in the USA Soft Landing Hubs: Initial Contact point for California

Through the ENRICH J-1 Soft Landing Programs, interested participants can access Incubators/Innovation Centers of Universities dedicated to R&I in the Transport & Connected and Automated Driving domain.

Location of the **ENRICH in the USA Soft Landing Programs** in California is the Citris Berkeley University. CalPoly University, located in the South of the Bay Area is also a vetted ENRICH Soft Landing location.

The University of California (UC), Berkeley is one of the world's preeminent public universities, boasting a distinguished faculty (with 22 Nobel laureates to date), stellar research libraries, and more than 350 academic programs. At the heart of Berkeley's excellence are its 1,582 full-time faculty members, dispersed among 130 academic units and 80 interdisciplinary research units, including work in the domain of Transport & Connected and Automated Driving. Aside from offering several programs and booth camps focused on the research and innovation in the field of Transport & Connected and Automated Driving research, UC Berkley is soft landing site for the **ENRICH in the USA.**

Located at **UC Berkley's Center for Information Technology Research in the Interest of Society (CITRIS) and the Banatao Institute is also the ENRICH in the USA Soft Landing Hub.** The institute has an objective to leverage the research strengths of the University of California campuses at Berkeley, Davis, Merced, and Santa Cruz and operate within the greater ecosystem of the University and the innovative and entrepreneurial spirit of Silicon Valley. In particular, strengthen bridges between world-class laboratory research, state and national policymakers, and companies and startups creating new applications and reshaping entire industries. Thus, the CITRIS and the Banatao Institute facilitate interdisciplinary work, including the work in the area of Transport & Connected and Automated Driving, among hundreds of University of California faculty members, students, corporate partners, and international institutions.

Michigan Automotive Cluster, State of Illinois

[82] https://static1.squarespace.com/static/54b4afe7e4b096f7dca62bef/t/55a7e4afe4b079318ff0d68d/1437066415176/2+The+Silicon+Valley+Ecosystem+2015.pdf
[83] https://qz.com/1072873/all-of-the-car-companies-suppliers-and-auto-startups-in-silicon-valley/
[84] https://qz.com/1034116/the-entangling-alliances-of-the-self-driving-car-world-visualized/

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The Michigan Automotive Cluster is internationally recognized as a preeminent place for auto-related R&D, where key industry players have the opportunity to cooperate with top-notch universities and research centers, such as Michigan State University, Michigan Technological University, Wayne State University, among others[85,86]. Therefore, this cluster comprises a skilled workforce, advanced R&D facilities and leading universities with recognized research groups focused on C&AV. Michigan is also home to the R&D Headquarters of companies such as Fiat Chrysler Automobiles, Ford Motor and General Motors[87].

Fiat Chrysler Automobiles, Ford Motor and General Motors are highly engaged in C&AD projects based in Detroit. The University of Michigan has also created a 32-acre center for testing C&AV in Ann Arbor, which is called Mcity[88]. Michigan's new laws allow the testing of C&AV that have no steering wheel and brake pedals, which allows companies, universities and research groups to perform more extensive tests on C&AV. In this context, General Motors is planning to start testing C&AV in Michigan's public roads[89].

ENRICH in the USA Soft Landing Hubs: **Initial Contact point for Illinois**

Through the ENRICH J-1 Soft Landing Programs, interested participants can access Incubators/Innovation Centers dedicated to R&I in the Transport & Connected and Automated Driving domain.

Locations for the **ENRICH in the USA Soft Landing Programs** in the closest proximity of the Maryland area is the **ENRICH in the USA Federal Center, Washington D.C** and **George Mason University, VA**.

ENRICH in the USA Federal Centre in D.C. is located **at the National Council of University Research Administrators** premises**.** The Centre is home to **ENRICH in the USA Government Landing Hub,** which connects companies and researchers with the US Government agencies and contractors. With its own centre, the Hub provides a great location for B2G and Research Development activities related Transport & Connected and Automated Driving. The Hub brings together more than 20 partners, which include government agencies, accelerators, incubators, universities, schools, and co-working spaces in the D.C. area. The US Government agencies that are partners and can be of interest for SMEs and researchers from the Transport & Connected and Automated Driving domain include DoE, DoD, DoT, NIH, USDA and NSF.

George Mason University is a public, coeducational institution of higher learning in Fairfax, Virginia, US It consists of 12 colleges and schools offering a variety of undergraduate and graduate degrees. Several of its graduate programs have been recognized nationally for excellence and distinction, including the Center for Retail Transformation, which aims at supporting and developing strategic partnerships and alliances with retail

[85] http://1419891vq14j2fapah1bpghjzyq.wpengine.netdna-cdn.com/wp-content/uploads/2016/02/Michigan-is-Auto_Talent-and-RD.pdf
[86] http://www.isc.hbs.edu/resources/courses/moc-course-at-harvard/Documents/pdf/student-projects/USA_Automotive_2009.pdf
[87] http://www.detroitchamber.com/industry-clusters/automotive/
[88] https://www.nytimes.com/2017/07/09/business/driverless-car-autonomous-university-michigan.html?mcubz=1
[89] https://www.nytimes.com/2016/12/20/business/silicon-valley-dominating-self-driving-tech-motor-city-says-not-so-fast.html?mcubz=1

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sector leaders, trade associations, and key government entities with oversight and interaction with the retail sector. The center has recently collaborated with Fairfax County on a development of all-electric autonomous shuttle program[90].

The University is also the location of the **ENRICH in the USA Smart City / Infrastructure Landing Hub**, which includes Virginia Tech University and Smart City Works as partners.

NW 33 Automotive Cluster, State of Oklahoma

The NW 33 Automotive Cluster is home to some of the most advanced automotive research facilities in the US. This cluster comprises a large network of leading universities, research centers and automotive industry players, such as Ohio State University, University of Cincinnati, University of Dayton, NHTSA Vehicle Research Test Center, Nissan Brake, among others[91].

NW 33 Automotive Cluster offers a highly innovative ecosystem with advanced resources and collaborative partners investing in C&AD research, development and testing[92]. In this context, Fiat Chrysler and GM-Powertrain have already announced their plan to invest in their Toledo operations in the field of C&AV[93]. The 33 Smart Corridor is also a key element of Ohio's Smart Mobility Initiative and will bring several benefits for the members of the NW 33 Automotive Cluster[94].

ENRICH in the USA Soft Landing Hubs: **Initial Contact point for Oklahoma**

Through the ENRICH J-1 Soft-Landing Programs, interested participants can access Incubators/Innovation Centers dedicated to R&I in the Transport & Connected and Automated Driving domain.

ENRICH in the USA affiliated partner site in Texas is hosted by the **Dallas Innovation Alliance.** It is also the affiliated partner site **in the closest proximity of Colorado.**

Located in Dallas, Texas and hosted by the **Dallas Innovation Alliance** (DIA) and their **Innov8te Incubator**, the **ENRICH in the USA Smart City Landing Hub** welcomes EU research, innovation, and business stakeholders who work within smart city applications. The city of Dallas, with DIA at the helm, has had over ten years of government officials and industrial giants collaboratively transforming parts of the city into a "living lab", enabling state of the art solutions in smart city solutions, including technologies related to Transport & Connected and Automated Driving, to find a real-world, real-time urban demonstration site.

Based in the state capital of Texas, Austin, are also the **Tech Ranch**, an **ENRICH Texas Hub Partner** and a venture accelerator, and the **University of Texas at Austin (UT Austin)** one of the **ENRICH in the USA** partnering institutions and the flagship institution of the University of Texas System.

[90] https://www2.gmu.edu/news/2021-06/mason-joins-research-effort-self-driving-shuttle-project
[91] http://www.33smartcorridor.com/cluster
[92] http://rgp.org/key-industries/automotive/
[93] http://toledo.gm.com/Facilities/public/us/en/toledo/news.html
[94] http://www.33smartcorridor.com/mobility

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In particular, **Tech Ranch** is an accelerator comprised of a global ecosystem of entrepreneurs, businesses, investors and community leaders. The accelerator aims to equip entrepreneurs and ecosystems with insights, proven techniques, tools, and processes that develop the business, community, and global impact.

Massachusetts Robotics Cluster, State of Massachusetts

The Massachusetts Robotics Cluster is acknowledged internationally as a front runner in advanced robotics. Massachusetts is recognized as a leading cluster for the development of unmanned vehicles and advanced manipulation technologies. Moreover, Massachusetts is home to a large network of leading universities and research centers, such as MIT, Harvard University, the University of Massachusetts, Boston University, among others, which often cooperate with companies to develop and implement new technologies. In this cluster, over 2,100 workers are engaged in the development of service robotics products and technologies, which has resulted in a total of $576 million in revenues for the companies employing them[95].

C&AD is a growing area that plays an important role for the Massachusetts cluster. Massachusetts is home to some of the key C&AD companies and research centers, such as nuTonomy, Optimus Ride and Toyota Research Institute (TRI). Currently, Massachusetts has a leading combination of recognized universities and private robots companies that are focused in developing and testing cutting edge technologies in the field of C&AD[96, 97].

ENRICH in the USA Soft Landing Hubs: **Initial Contact point for Massachusetts**

Through the ENRICH J-1 Soft Landing Programs, interested participants can access Incubators/Innovation Centers of Universities dedicated to R&I in the Transport & Connected and Automated Driving domain.

UMass is the only public research system in Massachusetts. The university system includes five campuses (Amherst, Boston, Dartmouth, Lowell, and a medical school in Worcester), and a satellite campus. UMass is planned to be the home of **ENRICH in the USA HealthTech and Smart "everything" Landing Hub**. With more than 20 partners from academia, industry, and government, the Hub will cover all sectors with a strong focus on cutting edge technologies with applications health. It should be highlighted that the Hub's partnership with UMass is a great opportunity for SMEs and researchers working on health technologies as UMass one of the major facilitators of innovation in the US Transport & CAD R&D. In particular, UMass is home to several initiatives, including the **UMass Transportation Center**[98], which aims to improving transportation, mobility and

[95] http://www.masstech.org/sites/mtc/files/documents/mass_robotics/Massachusetts%20Robotics%20Cluster%20Report%20Final.pdf
[96] https://www.roboticsbusinessreview.com/research/robot-cluster-focus-keeps-massachusetts-lead/
[97] http://www.masstech.org/sites/mtc/files/documents/mass_robotics/Massachusetts%20Robotics%20Cluster%20Report%20Final.pdf

[98] https://www.umasstransportationcenter.org/umtc/default.asp

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safety with innovative technologies and strategies**.** In addition, College of Engineering at the UMass Amherst is also home to a number of department and research groups dedicated to transport & CAD research[99, 100].

Cluster for Unmanned Vehicles and Robotics (CUVR), State of Pennsylvania

CURV is focused on unmanned vehicles and robotics and supports all forms of locomotion. This cluster comprises a large network of leading universities, research centers, companies and regional Technology Based Economic Development Organizations, such as Carnegie Mellon University, the Center for the Foundations of Robotics and the National Robotics Engineering Center[101]. Currently, Pittsburgh is home to one of the most important robotics community in the US[102].

Delphi and Uber have been testing their fleet of self-driving vehicles on Pittsburgh roads. In fact, Pittsburgh plays a very important role in R&D of components for C&AV. Furthermore, Carnegie Mellon University and Uber are key players in the field of C&AD and, therefore, the CURV is expected to have a leading role in C&AD[103].

ENRICH in the USA Soft Landing Hubs: Initial Contact point for Pennsylvania

Through the ENRICH J-1 Soft Landing Programs, interested participants can access Incubators/Innovation centers and partners dedicated to R&I in the Transport & Connected and Automated Driving domain.

State of Pennsylvania is home to one of the ENRICH in the USA's partner universities, **Temple University**. Temple University is a public research and higher education institution that was founded in 1884. As a Carnegie Classified R1 "Doctoral University with Highest Research Activity'' institution, and with a total operating budget of $1.29B (fiscal year 2020), Temple University runs a variety of research, education, and commercialization centers and institutes. Temple University is also a home to the **Small Business Development Center (SBDC),** which is an outreach center of the Fox School of Business and Management where the highly trained and experienced staff provides local and international entrepreneurs with professional knowledge and assistance. Its mission is to help pre-venture, startups, and SMEs grow and succeed locally and internationally. Since January 2021, Temple SBDC is the US lead and coordinator of the North American ENRICH in the USA network of Hubs and University-based Soft Landing incubators[104].

[99] https://mie.umass.edu/news/automated-vehicle-research

[100] https://cee.umass.edu/transportation-research

[101] http://www.cuvr.org/Industry.html

[102] http://www.pghtech.org/news-publications/state-of-the-industry-report/robotics-in-the-pittsburgh-region.aspx#.WdOi12hSwdU

[103] http://www.govtech.com/fs/Pennsylvania-Unveils-Guidelines-for-Autonomous-Vehicles.html

[104] https://enrichintheusa.com/temple-university-sbdc

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3 Recognized research networks/ professional associations and events

Research networks and professional associations play a crucial role in fostering interaction between academia, industry and federal/state entities. Research networks are collaborative forums that foster interaction between researchers and stimulate information exchange[105,106]; whereas a professional association is a body of practitioners of a given profession, formed usually to control entry into the profession, maintain standards, and represent the profession in discussions with other relevant bodies[107,108].

In the US, research networks are highly focused on science and engineering research and education. The US government supports a large variety of research networks focused on the country's priorities, such as electronics research. Since C&AD is a very recent area and the connection between academia and industry is already fostered by industry clusters and industry–university research centers, there are few US research networks focused on C&AD. This is very different from the scenario in the EU or in Canada, where research networks are required to strengthen cooperation between research groups.

Professional associations are also a crucial segment of the nonprofit sector in the US. According to the latest information available, membership organizations alone employed over 1.3 million people in the US[109]. It is important to note that professional and trade associations are simply one segment of the membership organization community. Thus, many new associations are created each year in the US, especially associations focused on the fastest-growing industries, such as C&AD.

The organization of conferences and events is one of the main activities of research networks and professional associations; therefore, a review of the US conferences and events that are focused on C&AD was conducted to identify the most relevant research networks and professional associations in this area.

Through gaining knowledge of the relevant research networks and organized conferences, one can determine the most effective approach to establishing relevant contacts in the US research community in order to pursue research collaborative opportunities.

[105] https://www.ecb.europa.eu/pub/economic-research/research-networks/html/index.en.html
[106] https://councilforeuropeanstudies.org/research/research-networks
[107] https://www.vocabulary.com/dictionary/professional%20association
[108] http://www.dictionary.com/browse/professional-association
[109] http://www.thepowerofa.org/wp-content/uploads/2012/03/PowerofAssociations-2015.pdf

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3.1. Research networks and professional associations

Association for Unmanned Vehicle Systems International (AUVSI)

The AUVSI is a nonprofit organization focused on advancing the unmanned systems and robotics community. The AUVSI brings together members from industry, academia and government organizations with the aim to foster, develop and promote unmanned systems and robotics technologies. Due to the importance of C&AD research, AUVSI is highly focused on promoting initiatives related to this field, such as webinars on C&AV technology, as well as the Automated Vehicles Symposium.

http://www.auvsi.org/

Connected Vehicle Trade Association (CVTA)

The CVTA is a nonprofit organization that has the mission to facilitate the interaction between entities involved in the vehicle communication environment. CVTA's membership includes companies, organizations, and governmental bodies engaged in developing bidirectional vehicle communications. In order to achieve its mission the CVTA is involved in the organization of several international conferences related with C&AD, such as Connected Cars Summit, International Conference on Future Mobility and Annual Conference and Exhibition ADAS & Autonomous Vehicles USA.

www.connectedvehicle.org/

Institute of Electrical and Electronics Engineers (IEEE) Intelligent Transportation Systems Society (ITSS)

IEEE is one of the world's largest technical professional organizations focused on advancing technology for the benefit of humanity. IEEE has members in over 160 countries, which collaborate on advanced technologies, such as computing, sustainable energy systems, robotics, healthcare, among others. The IEEE ITSS is a society under the umbrella of IEEE that aims to foster the theoretical, experimental, and operational aspects of Electrical Engineering and Information Technologies as applied to intelligent transportation systems (ITS). Although the IEEE ITSS is an international association, it is based in the US and has a large membership represented by scientists from US universities and research centers. IEEE ITSS is focused on an interdisciplinary activity that includes the promotion, consolidation and coordination of ITS technical activities. Moreover, IEEE ITSS has sponsored several conferences and networking events focused on C&AD, namely the Intelligent Vehicles Symposium (IV'17) in California, which aimed to bring together researchers, engineers, industry, universities and government agencies to discuss research and applications for Intelligent Vehicles and Vehicle-Infrastructure Cooperation[110].

[110] http://iv2017.org/

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www.ieee-itss.org

The Intelligent Transportation Society of America (ITS America)

ITS America is an organization dedicated to advancing the research, development and deployment of intelligent transportation systems. ITS America promotes public and regulatory policies that foster the development of intelligent transportation technologies throughout the US. Currently, there are 25 ITS America State Chapters such as the Intelligent Transportation Society of California (ITS CA), which is a public/private partnership with the mission to foster the development and deployment of ITS in California. ITS-CA is focused in facilitating industry-driven partnerships to promote the creation of an efficient transportation system in California. Furthermore, ITS-CA organizes the ITS California Annual Conference and Exhibition, which is focused on smart transportation and C&AD.

https://www.itsa.org/

http://www.itscalifornia.org

Society for Imaging Science and Technology

Society for Imaging Science and Technology is professional organization focused on keeping its members updated on the latest scientific and technological developments in the field of imaging. Society for Imaging Science and Technology is highly focused in promoting all aspects of imaging science, such as C&AD, through the organization of recognized conferences. In this context, this organization will sponsor the Autonomous Vehicles and Machines 2018, a conference focused on how advancements in sensing, computing, imaging processing, and computer vision technologies enable research on C&AD.

www.imaging.org/site/IST/IST/

USCAR: The United States Council for Automotive Research

USCAR is a council for automotive research that has the mission to strengthen the technology base of the US auto industry through cooperative R&D. USCAR's mission is accomplished through partnerships with various stakeholders including the Federal Government, educational institutions and suppliers. In 2017 USCAR sponsored the IEEE-SA Ethernet & IP @ Automotive Technology Day (EIP@ATD) conference in California, which was focused on how Ethernet supports C&AV[111].

www.uscar.org/guest/index.php

[111]https://standards.ieee.org/events/automotive/2017_ieee-sa_eipatd_exhibitor-sponsor_prospectus.pdf

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3.2. Conferences and other networking events

Conferences and other networking events are crucial to enhance the connection between researchers (both nationally and internationally), and between academia and industry. They provide a great opportunity for researchers and industry representatives from C&AD research related fields to meet in person, promoting knowledge and experience sharing and, in some cases, the establishment of R&D partnerships.

The geographic distribution of the US conferences and other networking events related to C&AD reveals a high degree of spatial concentration in two states: California and Michigan. In addition, the identified conferences and other networking events are also highly concentrated in the first six months of the year. However, the dates and location of some of the identified events still need to be determined.

Since C&AD is a fast-growing research area in the US, the number of conferences and other networking events focused on C&AD research related fields has been increasing. Thus, some of the main conferences and other networking events focused on C&AD were identified in this research handbook by desk research, which included an extensive literature review and a review of the conferences sponsored by recognized professional associations in the C&AD area.

Most conferences and events in the C&AD area based in the US are held annually, but the majority do not have peer review processes for publishing proceeding articles. This is possibly because the fierce competition in this area makes academic and industry players more reluctant to share knowledge and technology than in other areas.

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Table 3 - Conferences and Other Networking Events

Date	Conference/event title	Interval	Location	Research areas	Internet link
January 16 – February 20, 2022	Autonomous Vehicles and Machines 2022	Annual	Virtual	AI and CPSs	https://www.imaging.org/site/IST/IST/Conferences/EI/EI_2022/Conference/C_AVM.aspx
20-22 February 20, 2022	Auto.AI USA	First edition	San Francisco, California	AI and CPSs	https://www.auto-ai.com/
21-22 February, 2022	Car HMi USA	Annual	Detroit, Michigan	AI, CPSs and Wireless Communication	https://www.car-hmi-usa.com/
7-9 March, 2022	International Conference on Connected Vehicles and Expo	Annual	Virtual/ Florida Polytechnic University, Florida	CPSs and Wireless Communication	https://iccve2022.org/
21-24 March, 2022	GTC 2022	Annual	Silicon Valley , California	AI, CPSs, Cybersecurity and Wireless Communication	https://www.nvidia.com/gtc/call-for-submissions/
10-12 May, 2022	AutoSens Conference	Annual	Detroit, Michigan	Possibly CPSs (as in the 2017 conference)	https://auto-sens.com/events/detroit/

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Date	Conference/event title	Interval	Location	Research areas	Internet link
16-18 May, 2022	Intelligent Transportation Society of California Annual Conference and Exhibition	Annual	Anaheim, California	Big Data and CPSs	https://www.itscalifornia.org/
1-2 October, 2021	AUTONOMOUS VEHICLES 2021	Annual	Huntington Beach, California	AI, CPSs, Wireless Communication	https://www.autonomous-vehicles-conference.com/
13-14 October, 2021	Annual Automotive Cyber Security Summit	Annual	Detroit, Michigan	Cybersecurity	https://automotiveisac.com/auto-isac-summit-2021/
25-27 October, 2021	2021 Pennsylvania Automated Vehicle Summit	Annual	Pittsburgh, Pennsylvania	AI, CPSs, Cybersecurity and Wireless Communication	http://cogsima2017.ieee-cogsima.org/
26-28 October, 2021	Autonomous Vehicle Technology Expo	Annual	Novi, Michigan	AI, CPSs, Wireless Communication	https://www.autonomousvehicletechnologyexpo.com/michigan/en/

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Date	Conference/event title	Interval	Location	Research areas	Internet link
15-16 November, 2021	TU-Automotive Detroit 2021	Annual	Detroit, Michigan	CPSs and Wireless Communication	https://www.tu-auto.com/event/
29 November – 1 December, 2021	Annual Florida Automated Vehicles Summit	Annual	Orlando, Florida	Cybersecurity and CPSs	https://favsummit.com/
Date to be determined, 2022	Escar USA - The World's Leading Automotive Cyber Security Conference	Annual	Location to be determined	Cybersecurity	https://www.escar.info/escar-usa.html
Date to be determined, 2022	Autonomous Vehicles Silicon Valley	Annual	Silicon Valley, California	CPSs	https://www.automotive-iq.com/events-autonomousvehicles

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4 US R&D initiatives and programs

The US R&D funding system is highly decentralized and comprises several actors, such as agencies of federal and state governments, universities, the private sector and non-profit organizations[112]. R&D is a driver of innovation and economic growth and, therefore, has particular importance for the aforementioned actors. In the US, the research developed by universities and research centers is highly supported by federal and state grants that prioritize research areas, which can lead to technological breakthroughs[113].

The US government has identified the importance of C&AD research for the future of mobility. Funding C&AD testing and research is currently a priority for federal and state agencies, which are focused on supporting the development of new advanced technologies. University and center research can be supported by federal or state funds, which are awarded according to specified criteria[114]. Federal agencies such as the DOD, DOT, NHTSA and NSF have developed several initiatives to support research in the field of C&AD; while state agencies such as the Michigan Department of Transportation (MDOT) and Colorado Department of Transportation (CDOT) have identified C&AD as a key research area.

A review of the US federal and state funding initiatives was conducted to identify the most relevant R&D initiatives and programs in the C&AD field. The following subsection provide descriptions of the initiatives and programs; while Annex 2 provides a summary table of the initiatives and programs.

[112] http://www.euussciencetechnology.eu/assets/content/documents/InnovationSystemInnovationPolicyUS.pdf
[113] http://www.itif.org/files/2011-university-research-funding.pdf
[114] http://www.itif.org/files/2011-university-research-funding.pdf

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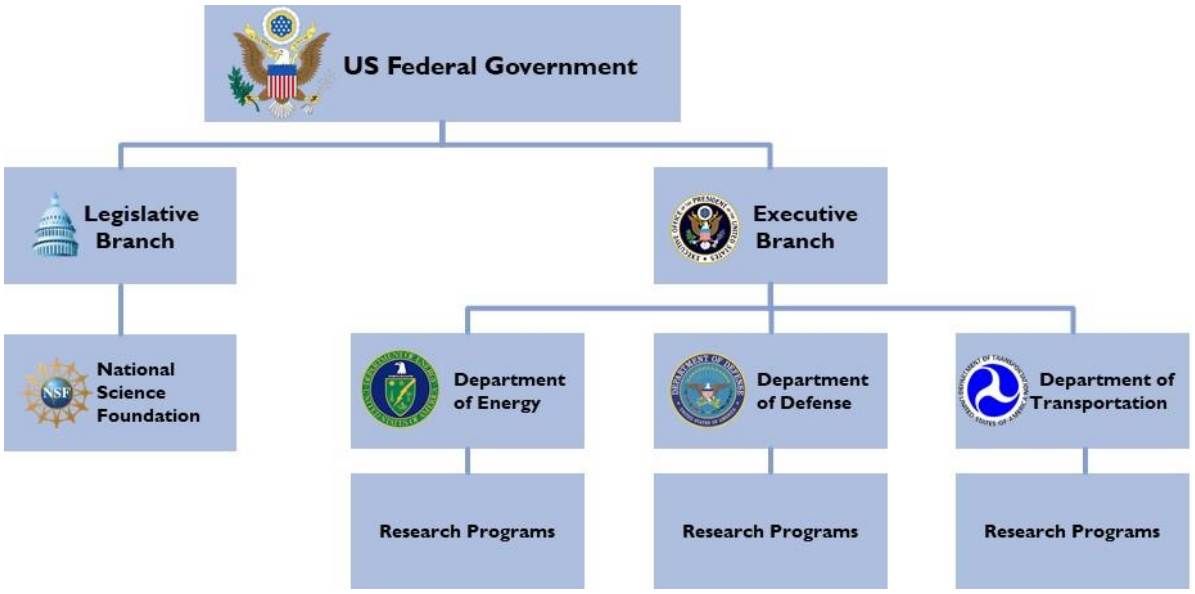

Figure 4 - US Government Organizational Chart

4.1. Federal initiatives/programs

The US Federal Government is prioritizing C&AD research through grants and opportunities for promoting cooperation with the national laboratories. These grants are highly competitive due to the amount of available dollars and the high response from the research community[115]. At the federal level, NHTSA, US Department of Energy (DOE), DOD, DOT and NSF are supporting research in C&AD[116]. The Federal Government R&D initiatives and programs are bound by their legislatively enacted missions and functions[117]. Furthermore, the federal agencies have subprograms to support C&AD innovations from early to advanced stages in development and testing. Therefore, a review of the US Federal Government R&D initiatives and programs was conducted to identify the most relevant ones in research fields related to C&AD.

[115] https://www.hklaw.com/energyfinanceblog/federal-funding-opportunities-for-connected-and-autonomous-vehicle-technologies-05-15-2017/
[116] http://www.wsp-pb.com/en/What-we-do/Strategic-Consulting/Insights/Governments-Role-in-Driverless-Cars-Today-and-Tomorrow/
[117] https://www.hklaw.com/energyfinanceblog/federal-funding-opportunities-for-connected-and-autonomous-vehicle-technologies-05-15-2017/

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4.1.1. National Science Foundation (NSF)

The NSF provides support through grants and cooperative agreements to universities, businesses, informal science organizations and other research organizations focused on areas that are most likely to result in spectacular technological progress[118]. In 2017, the NSF is working closely with multiple agencies of the Federal Government, such as DOT, Federal Highway Administration (FHWA) and DOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO)[119].

The NSF supports research initiatives, which aim to promote the development of knowledge based technologies in key research fields related to C&AD, such as Smart and Autonomous Systems (S&AS), CPSs, and Robust Intelligence.

The NSF supports cooperative research between universities and industry, as well as US researchers' participation in international scientific and engineering research activities. Indeed, collaboration between US researchers and European researchers can be funded in almost all new proposals to NSF or in supplements to existing NSF awards. Thus, European researchers interested in collaborating with US researchers could ask their US counterparts to contact the NSF disciplinary program officer or use the Office of International Science and Engineering (OISE) Regional and Country Contacts to inquire about funding possibilities[120].

First Approach	
European Union OISE Regional Contact	eeinfo@nsf.gov
Internet links	www.nsf.gov/od/oise/country-list.jsp www.nsf.gov/od/oise/europe/

Smart and Connected Communities (S&CC) program

https://beta.nsf.gov/funding/opportunities/smart-and-connected-communities-scc

The S&CC program supports research on Intelligent Physical Systems (IPS), supporting integrative research that addresses fundamental technological and social science dimensions of smart and connected communities and pilots solutions together with communities. The goal of the NSF Smart and Connected Communities (S&CC) program solicitation is to accelerate the creation of the scientific

[118] https://www.nsf.gov/about/how.jsp
[119] https://www.nsf.gov/pubs/2017/nsf17529/nsf17529.htm
[120] https://www.nsf.gov/od/oise/europe/

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and engineering foundations that will enable smart and connected communities to bring about new levels of economic opportunity and growth, safety and security, health and wellness, accessibility and inclusivity, and overall quality of life[121].

First Approach	
Contact Person	European researchers interested in international collaborations could contact the Program Director, OD/OISE, David Corman
Email	dcorman@nsf.gov
Phone Number	(703) 292-8754
Internet link	https://beta.nsf.gov/funding/opportunities/smart-and-connected-communities-scc

Cyber-Physical Systems (CPS) program

www.nsf.gov/funding/pgm_summ.jsp?pims_id=503286

The CPS program promotes the development of new and innovative ideas that will have high impact on the field of CPS. The proposals for the CPS program may be submitted by universities, research labs, non-profit and non-academic organizations. Moreover, in the field of C&AD, CPS research proposals should take into consideration the potential use of ITS JPO Connected Vehicle (CV) Testbeds[122].

The CPS program supported a team of researchers from Carnegie Mellon University to develop the parts to create the autonomous 2011 Cadillac SRX, which has six laser sensors, six radar units, three cameras and one thermal camera[123].

First Approach	
Contact Person	European researchers interested in international collaborations could contact the Program Director, David Corman[124].
Email	dcorman@nsf.gov
Phone Number	(703) 292-8754
Internet link	www.nsf.gov/pubs/2017/nsf17529/nsf17529.htm

[121] https://beta.nsf.gov/funding/opportunities/smart-and-connected-communities-scc
[122] https://www.nsf.gov/pubs/2017/nsf17529/nsf17529.htm
[123] https://www.nsf.gov/news/news_summ.jsp?cntn_id=190831
[124] https://www.nsf.gov/pubs/2017/nsf17529/nsf17529.htm

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Robust Intelligence (RI) program

www.nsf.gov/funding/pgm_summ.jsp?pims_id=503305

The RI program includes all aspects of the computational understanding and modeling of intelligence in complex and realistic contexts. This program incorporates the research of AI, computer vision, human language research, robotics, machine learning, computational neuroscience and other related areas[125]. The proposals for the RI program can be submitted by universities, research labs, non-profit and non-academic organizations[126].

Furthermore, the NSF's RI program supports foundational research in the field of AI that can lead to the development of smart systems that are crucial for C&AD. In this context, the NSF has provided an important support to the theoretical work and experiments that are being conducted by the Resource-Bounded Reasoning Lab to develop safe semi-autonomous systems (SAS), such as self-driving cars[127].

First Approach	
Contact Person	European researchers interested in international collaborations could contact the RI Contact Point, James Donlon[128].
Email	jdonlon@nsf.gov
Phone Number	(703) 292-8074
Internet link	www.nsf.gov/staff/sub_div.jsp?org=IIS&orgId=3947&from_org=IIS

4.1.2. Department of Energy (DOE)

The DOE is highly committed to support advanced transportation projects focused on energy efficient mobility systems, including C&AD. In this context, the DOE has initiatives and subprograms focused on promoting smart mobility and C&AD. Within DOE, the Office of Energy Efficiency and Renewable Energy (EERE) leads US researchers and other partners in making transportation cleaner and more efficient through solutions that put electric drive vehicles on the road and replace oil with clean domestic fuels. Through Vehicle, Bioenergy, and Hydrogen and Fuel Cell Technologies offices, EERE advances the development of next-generation technologies to improve plug-in electric and other

[125] https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503305
[126] https://nsf.gov/pubs/2017/nsf17572/nsf17572.htm
[127] https://www.umass.edu/newsoffice/article/umass-amherst-research-advances-self
[128] https://nsf.gov/pubs/2017/nsf17572/nsf17572.htm

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alternative-fuel vehicles, advanced combustion engine and vehicle efficiency, and produce low-carbon domestic transportation fuels[129].

Energy Efficient Mobility Systems (EEMS) subprogram and Vehicle Technologies Office (VTO)

www.energy.gov/eere/vehicles/energy-efficient-mobility-systems

The VTO supports high impact projects that can significantly advance its mission to develop more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum. The EEMS Program supports VTO's mission to improve transportation energy efficiency through low-cost, secure, and clean energy technologies. EEMS conducts early-stage research and development (R&D) at the vehicle, traveller, and system levels, creating knowledge, insights, tools, and technology solutions that increase mobility energy productivity for individuals and businesses[130].

In FY2020, the EEMS Program concluded the first phase of research under "**SMART Mobility 1.0,"** a 3-year effort consisting of 5 national laboratories and 30+ projects. Building upon the research results and insights from the first phase of SMART Mobility, EEMS launched **"SMART Mobility 2.0"** in FY2020. SMART Mobility 2.0 is comprised of 6 National Laboratories and supports continuing research from SMART 1.0 as well as new research projects. The Consortium is the EEMS Program's primary effort to create tools and generate knowledge about how future mobility systems may evolve and identify R&D gaps that the EEMS Program may address through its research portfolio[131].

First Approach	
Information about Grants	European researchers can find official notices for Open Funding Opportunities at Grants.gov or at the EERE Exchange website. European researchers interested in receiving funding from the Office of Energy Efficiency and Renewable Energy could contact the point of contact identified in the funding opportunities[132].
Internet link	https://www.energy.gov/eere/funding-opportunities https://epicweb.ee.doe.gov/EPICWeb/#/home

[129] https://www.energy.gov/eere/sustainable-transportation

[130] https://www.energy.gov/eere/funding-opportunities

[131] https://www.energy.gov/eere/vehicles/energy-efficient-mobility-systems

[132] https://energy.gov/eere/vehicles/funding-opportunities

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

In August of 2021, DOE unveiled two funding opportunities totalling more than $162 million to improve efficiency and reduce carbon emissions among cars, trucks, and off-road vehicles: **Super Truck 3 and Low Greenhouse Gas Vehicle Technologies initiatives.**

DOE's SuperTruck 3 Initiative

New technologies, business models, and consumer demands are among several factors changing how freight moves in the US. To this end, DOE's Office of Energy Efficiency and Renewable Energy (EERE) initially launched the SuperTruck initiatives in 2009, aimed to improve heavy-duty truck freight efficiency by 50%, while the follow-up SuperTruck 2 in 2016 sought to double fuel efficiency for 18-wheeler ("class 8") trucks[133]. The initiatives attracted participation of truck makers comprising over 99% of the U.S. truck market. With that in mind, the purpose of **SuperTruck 3** initiative is to solicit innovative R&D concepts to enable medium- and heavy-duty original equipment manufacturers (OEMs), suppliers, and fleet partners to develop higher efficiency trucks and freight systems that significantly reduce CO_2 emissions while meeting future criterion emission standards. DOE is seeking vehicle-level efficiency improvements for Class 7-8 regional-haul/long-haul trucks and Class 4-6 vocational trucks as well as system-level freight efficiency improvement (Class 4-8) beyond vehicle hardware. Projects will focus on real world operation with drive-cycle-based fuel economy including representative hub-to-hub routes and last-mile delivery.

Continued engine research will further optimize efficiency, reduce emissions and allow the use of biofuels and hydrogen, including powertrain AI control for hybrid applications. Projects will pursue a focus on electrification, including hydrogen and fuel cell technology (including hybridization strategies such as fuel cell range extenders), battery electric and plug-in hybrid systems. Projects may also utilize automation/connectivity capabilities to further improve freight efficiency. Fleets operators and companies with large captive fleets are encouraged to be integral parts of teams, from analysis to technology development, and may also lead teams, along with vehicle manufacturers or major suppliers[134].

First Approach	
Information about Grants	European researchers interested in participating in this initiative could look carefully for administrative information and application requirements at Grants.gov or at EERE Exchange website. For further information European researchers could contact the point of contact identified in the funding opportunities[135]

[133] https://www.energy.gov/articles/doe-announces-162-million-decarbonize-cars-and-trucks

[134] https://eere-exchange.energy.gov/Default.aspx#FoaIdbba83da0-9b58-4d26-8c6a-4a36230aed4f

[135] https://www.energy.gov/eere/articles/doe-announces-15-million-accelerate-deployment-energy-efficient-transportation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

	Additional contact points regarding the initiative: *eere-exchangesupport@hq.doe.gov* *DE-FOA-0002450@netl.doe.gov*
Internet link	https://eere-exchange.energy.gov/Default.aspx#FoaIdbba83da0-9b58-4d26-8c6a-4a36230aed4f

DOE's Low Greenhouse Gas Vehicle Technologies Initiative

DOE is also offering up to $62.75 million as part of its "Low Greenhouse Gas Vehicle Technologies Research, Development, Demonstration, and Deployment" FOA for innovative solutions to reducing emissions and increasing efficiencies for on- and off-road vehicles[136]. In particular, this intiative aims to advance the Biden Administration's goals to achieve carbon pollution-free electricity by 2035 and "deliver an equitable, clean energy future, and put the United States on a path to achieve net-zero emissions, economy-wide, by no later than 2050".

Thus, the intiative seeks projects across the following areas: electric vehicle community partner demonstration projects; electric vehicle workplace charging projects; RDD&D of technologies to reduce the cost of EV chargers, advanced engines and fuels that reduce emissions, including natural gas, propane, and dimethyl ether; and, innovative solutions for medium/heavy duty on- and off-road vehicles including electrification and high-power charging[137].

First Approach	
Information about Grants	European researchers interested in participating in this initiative could look carefully for administrative information and application requirements at Grants.gov or at EERE Exchange website. For further information European researchers could contact the point of contact identified in the funding opportunities[138] Additional contact points regarding the initiative: *EERE-ExchangeSupport@hq.doe.gov* *DE-FOA-0002475@netl.doe.gov*

[136] https://www.energy.gov/articles/doe-announces-162-million-decarbonize-cars-and-trucks

[137] https://eere-exchange.energy.gov/Default.aspx#FoaIdbba83da0-9b58-4d26-8c6a-4a36230aed4f

[138] https://www.energy.gov/eere/articles/doe-announces-15-million-accelerate-deployment-energy-efficient-transportation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

Internet link	https://eere-exchange.energy.gov/Default.aspx#FoaIdbba83da0-9b58-4d26-8c6a-4a36230aed4f

4.1.3. Department of Defense (DOD)

In the US, autonomous vehicles are widely used in military operations. In fact, DOD related research is often the stimulus for new and highly innovative technologies that are transferred to private sector applications, such as the Internet, GPS, etc. Autonomous vehicles have proven to be highly relevant for different types of missions[139]. Thus, the DOD is focused on fostering and accelerating the development of C&AV that can be used to transport military supplies and carry out military missions without endangering the lives of military personnel[140].

Many of the R&D initiatives have restrictions towards foreign research involvement on the more classified fields. Nevertheless, some of the existing R&D initiatives and policies established by the DOD are eligible to foreign individuals and organizations. However, foreign applicants need to complete some additional steps during the application process compared to domestic applicants. For instance, the foreign applicants may need to file a US tax return which requires a Taxpayer Identification Number, also referred to as an Employer Identification Number[141].

DARPA Explainable Artificial Intelligence (XAI) Program

www.darpa.mil/program/explainable-artificial-intelligence

Defense Advanced Research Projects Agency (DARPA) is the arm of the DOD in advanced military technology research. DARPA has the mission to make key investments in breakthrough technologies for national security, which include the field of C&AD[142].

The DARPA XAI program aims to develop machine learning techniques focused on addressing challenges in two areas: machine learning problems to classify events of interest in heterogeneous data and machine learning problems to construct decision policies for an autonomous system to perform a variety of simulated missions[143].

First Approach

[139] https://www.nap.edu/read/11379/chapter/2
[140] https://www.livescience.com/44272-darpa-self-driving-car-revolution.html
[141] https://www.grants.gov/web/grants/learn-grants/grant-eligibility.html
[142] https://www.darpa.mil/about-us/about-darpa
[143] https://www.darpa.mil/program/explainable-artificial-intelligence

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

Information about Non-US eligibility for the program	Non-US organizations and/or researchers can apply to the DARPA XAI program to the extent that such participants fulfill necessary nondisclosure agreements, security regulations, export control laws, and other governing statutes applicable under the circumstances[144].
Internet link	https://www.darpa.mil/program/explainable-artificial-intelligence

Human Interaction with Autonomous Systems Program

https://www.onr.navy.mil/en/Science-Technology/Departments/Code-34/All-Programs/human-bioengineered-systems-341/human-interaction-with-autonomous-systems#:~:text=The%20Human%20Interaction%20with%20Autonomous,intelligent%20agents%20and%20autonomous%20systems.

The Human Interaction with Autonomous Systems Program has been created by the Office of Naval Research, which is an executive branch agency within the US DOD[145]. The Program aims at developing methods and technologies to enable warfighters and robots or autonomous systems to collaborate as peers. It includes the development of human-centric autonomous vehicles and robotic teammates that collaborate with humans in a peer-to-peer manner and research on high-level natural language communication with autonomous systems. Currently, one of the objectives of this program is to develop technologies that allow the integration of perception and intuitive interfaces with mission-capable humanoid robots[146].

First Approach	
Contact Person	European researchers interested in international collaborations could contact the Program Officer, Thomas McKenna[147].
Email	tom.mckenna@navy.mil
Internet link	www.onr.navy.mil/en/Science-Technology/Departments/Code-34/All-Programs/human-bioengineered-systems-341/Human-Robot-Interaction

Cyber Security and Complex Software Systems Program

[144] https://www.darpa.mil/attachments/DARPA-BAA-16-53.pdf
[145] https://www.onr.navy.mil/About-ONR
[146] https://www.onr.navy.mil/en/Science-Technology/Departments/Code-34/All-Programs/human-bioengineered-systems-341/Human-Robot-Interaction
[147] https://www.onr.navy.mil/en/Science-Technology/Departments/Code-34/All-Programs/human-bioengineered-systems-341/Human-Robot-Interaction

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

www.onr.navy.mil/Science-Technology/Departments/Code-31/All-Programs/311-Mathematics-Computers-Research/Cyber-Security-Software

The Office of Naval Research Cyber Security and Complex Software Systems Program aims to develop principles and models for the design and implementation of complex software systems that meet the required guarantees for security, reliability and performance. The Cyber Security sub-program is heavily focused on automation and autonomy in the cybersecurity environment. The program has emphasis in several research areas related to the field of C&AD, such as: Information Assurance of Cyber-Physical Systems; Trusted Network Computing; Secure Information Management, Sharing and Interaction; and Principles for Correctness and Security Properties[148].

First Approach	
Contact Person	European researchers interested in international collaborations could contact the Program Officer, Dr. Dan Koller[149].
Email	daniel.koller1@navy.mil
Phone Number	(703) 696-5031
Internet link	www.onr.navy.mil/Science-Technology/Departments/Code-31/All-Programs/311-Mathematics-Computers-Research/Cyber-Security-Software

Distributive and Collaborative Intelligent Systems

The Distributive and Collaborative Intelligent Systems initiative is founded by the US Army Research Office Laboratory (ARL) as a part of a wider ARL open campus initiative . Through the Open Campus initiative, ARL will leverage regional expertise and facilities to accelerate the discovery, innovation and transition of science and technology. Close collaboration with universities, start-ups, and established companies working in regionally specific technical subject areas will directly benefit the Soldier and ensure our nation's future strength and competitiveness in critical scientific engineering and the creative fields[150].

Distributive and Collaborative Intelligent Systems initiative is focused on developing the underpinning science to inform and shape future concepts to extend the reach, situational awareness, and

[148] https://www.onr.navy.mil/Science-Technology/Departments/Code-31/All-Programs/311-Mathematics-Computers-Research/Cyber-Security-Software
[149] https://www.onr.navy.mil/Science-Technology/Departments/Code-31/All-Programs/311-Mathematics-Computers-Research/Cyber-Security-Software

[150] https://www.arl.army.mil/opencampus/

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operational effectiveness of Intelligent System/Soldier teams against dynamic threats in complex and contested environments and provide technical and operational superiority through fast, intelligent, resilient, and collaborative behaviors. Focus is in three Research Areas in Distributed Intelligence, Heterogeneous Group Control, and Adaptive and Resilient Behaviors[151].

First Approach	
Contact Person	European researchers interested in collaborative intelligent systems could contact Principal Investigator, Brett Piekarski[152].
Email	brett.h.piekarski.civ@mail.mil
Phone Number	(301) 394-1263
Internet link	https://www.dcist.org/

4.1.4. Department of Transportation (DOT)

The DOT is highly committed to support research to advance the safe and effective use of C&AV. To accomplish this goal the DOT has created subprograms and initiatives to support C&AD innovations from early to advanced stages of technology development[153].

Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD)

www.fhwa.dot.gov/fastact/factsheets/advtranscongmgmtfs.cfm

The FAST Act created the ATCMTD to issue competitive grants for the development of advanced transportation technologies to improve safety, efficiency, system performance and infrastructure. Thus, giving the very broad implications of C&AV, the ATCMTD requires applicants to partner with a public entity (cities and municipalities) as the lead applicant[154,155].

First Approach

[151] https://www.arl.army.mil/opencampus/node/310
[152] https://www.arl.army.mil/www/default.cfm?page=332
[153] https://www.hklaw.com/energyfinanceblog/federal-funding-opportunities-for-connected-and-autonomous-vehicle-technologies-05-15-2017/
[154] https://www.fhwa.dot.gov/fastact/factsheets/advtranscongmgmtfs.cfm
[155] https://www.hklaw.com/energyfinanceblog/federal-funding-opportunities-for-connected-and-autonomous-vehicle-technologies-05-15-2017/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

Information about eligibility for the program	The Secretary of Transportation can carry out research, development, and technology transfer activities related to transportation by making grants to, or entering into contracts and cooperative agreements with, one or more of the following entities: 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[156].
Internet link	https://www.fhwa.dot.gov/fastact/funding.cfm

Connected Vehicle Pilot Deployment Program

www.its.dot.gov/pilots/

The Connected Vehicle Pilot Deployment Program aims to support pilot deployments of safe and climate smart C&AV[157]. The Connected Vehicle Pilot Deployment Program is sponsored by the DOT ITS JPO and aims to support testing and operationalization of advanced mobile and roadside technologies and enabling of several C&AD applications. The pilot deployments are expected to integrate connected vehicle research concepts into practical and effective elements, enhancing existing operational capabilities. The intent of these pilot deployments is to encourage partnerships of multiple stakeholders (e.g., private companies, States, transit agencies, commercial vehicle operators, and freight shippers) to deploy applications utilizing data captured from multiple sources (e.g., vehicles, mobile devices, and infrastructure) across all elements of the surface transportation system (i.e., transit, freeway, arterial, parking facilities, and tollways) to support improved system performance and enhanced performance-based management. The pilot deployments are also expected to support an impact assessment and evaluation effort that will inform a broader cost-benefit assessment of connected vehicle concepts and technologies[158].

First Approach	
Contact Person	European researchers interested in having specific information about participation in this program could contact CV Pilots Program Manager, Katherine K. Hartman[159].

[156] https://www.fhwa.dot.gov/fastact/nofo_atcmtd_20160325.pdf
[157] https://www.hklaw.com/energyfinanceblog/federal-funding-opportunities-for-connected-and-autonomous-vehicle-technologies-05-15-2017/

[158] https://www.its.dot.gov/pilots/overview.htm
[159] https://www.its.dot.gov/pilots/pilots_overview.htm

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

Email	Kate.Hartman@dot.gov
Phone Number	(202) 366-2742
Internet link	www.its.dot.gov/pilots/pilots_overview.htm

FHWA Exploratory Advanced Research (EAR) Program

www.fhwa.dot.gov/advancedresearch/about.cfm#pro

The FHWA EAR Program aims to support long–term and high–risk research with a high remuneration potential. This program is focused on identifying gaps faced by applied highway research programs in order to anticipate emerging issues with national implications[160].

The EAR study "Intersection Control for Autonomous Vehicles" aims to process traffic more efficiently than traffic lights and stop signs without reducing safety. This study was awarded by the FHWA EAR Program and is being conducted at the University of Texas (Austin)[161].

First Approach	
Contact Person	European researchers interested in having specific information about participation in this program could contact EAR Program Manager, David E, Kuehn[162].
Email	david.kuehn@dot.gov
Phone Number	(202) 493-3414
Internet link	www.fhwa.dot.gov/advancedresearch/about.cfm#gen

ITS Joint Program Office (ITS JPO)

www.its.dot.gov

The DOT ITS JPO is responsible for conducting research on behalf of the Department in the fields of advance transportation safety, mobility, and environmental sustainability through electronic and information technology applications. This program is focused on intelligent vehicles, intelligent infrastructure and the development of an intelligent transportation system. Therefore, the ITS JPO

[160] https://www.fhwa.dot.gov/advancedresearch/pubs/10023/index.cfm
[161] https://www.fhwa.dot.gov/advancedresearch/pubs/10023/index.cfm
[162] https://www.fhwa.dot.gov/advancedresearch/contacts.cfm

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

program supports C&AD research through investments in research initiatives, exploratory studies, technology transfer and training. In this context, the ITS JPO has established an Automated Vehicle Research program with the aim to foster the deployment of partially automated vehicle systems[163]

First Approach	
Contact Person	European researchers interested in having specific information about participation in this program could contact Connected Vehicle Safety & Automation Program Manager, Kevin Dopart[164].
Email	Kevin.Dopart@dot.gov
Phone Number	(202) 366-5004
Internet link	www.its.dot.gov/automated_vehicle/

4.2. State initiatives/programs

State initiatives are one of the major ways states can support public projects in key areas, such as transportation. Some US states are focused in being at the forefront of C&AD technology development. These states recognize the potential impact of developing initiatives that bring together companies, research facilities and testing programs[165]. Therefore, state agencies such as the CDOT are supporting important smart mobility initiatives that will contribute to the development of a mobility system focused on C&AV. Several state initiatives are provided as examples of what exist at the state level.

4.2.1. Colorado: Connected & Autonomous Technology Program

https://www.codot.gov/programs/innovativemobility/mobility-technology/cav-technology-program

Colorado Department of Transportation (CDOT) has developed a program that is dedicated to understanding how these changes influence the way we operate and maintain the US roadways.

The connected and autonomous technologies program helps CDOT navigate the coming changes, understand opportunities and challenges ahead, mitigate potential risks and enable an environment where connected and autonomous technologies can thrive as it becomes available. The program aims

[163] https://www.its.dot.gov/automated_vehicle/avr_plan.htm
[164] https://www.its.dot.gov/automated_vehicle/
[165] https://www.johndaylegal.com/state-laws-and-regulations.html

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

to create a transparent foundation for building meaningful partnerships with local, regional and national stakeholders so that Colorado benefits from collective progress[166].

First Approach	
Contact Person	European researchers interested in the CDOT Research Program could contact the Director of Mobility technology Ashley Nylen:
Email	ashley.nylen@state.co.us
Internet link	www.codot.gov/programs/research

4.2.2. Florida: Florida Automated Vehicles (FAV) program

https://www.fdot.gov/technology/initiatives/index.shtm

The FAV program, which was launched in 2014, is led by the Florida Department of Transportation (FDOT). The FAV initiative is focused on helping to educate the public for the deployment of C&AD technologies on public roadways. One of the key elements of the FAV program is public outreach and education, especially of the state's planning and engineering community[167].

In addition, FDOT is currently supporting a number of other initiatives related to Transport & CAD, such as Florida's Connected and Automated Vehicle Initiative[168], Driver Assisted Truck Platooning Pilot[169] and I-Street @ UF[170]

First Approach	
Contact Person	European researchers interested in the FDOT Research Programs and contracts could contact the FDOT office.
Email	fdot.servicedesk@dot.state.fl.us
Phone Number	(850) 414-4616
Internet link	www.fdot.gov/research/

[166] https://www.codot.gov/programs/innovativemobility/mobility-technology/cav-technology-program
[167] http://floridaav.hntb-tsc.com/

[168] https://www.fdot.gov/traffic/its/projects-deploy/cv/connected-vehicles

[169] https://www.fdot.gov/traffic/its/projects-deploy/cv/MapLocations/DATP.shtm

[170] https://www.transportation.institute.ufl.edu/research-2/istreet-about-us/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

4.2.3. Michigan: Michigan's Office for Future Mobility and Electrification

https://www.michiganbusiness.org/ofme/

The Office of Future Mobility and Electrification supports a comprehensive state wide approach to help government, education and the private sector succeed in growing the mobility and electrification industry in Michigan. In particular, the OFME has six objectives[171]:

- **Increase Mobility Investment in Michigan**: Generate new investment and job creation from tech companies focused on future mobility, including autonomous and electric vehicle innovation.
- **Expand Michigan's Smart Infrastructure**: Further develop systems for deploying autonomous and shared transportation.
- **Engage More Mobility Startups**: Establish Michigan as a premier location for young companies to start, scale, commercialize and grow technologies redefining the movement of people and goods.
- **Further Enable Michigan's Mobility Workforce:** Develop and attract the skills and talent necessary to meet the changing demands of the mobility sector.
- **Accelerate Electric Vehicle Adoption in Michigan:** Support the transition from internal combustion engine vehicles to electric vehicles and expand access to charging infrastructure.
- **Bolster Michigan's Mobility Manufacturing Core:** Protect the state's competitiveness in electric and autonomous vehicle manufacturing and ability to move technologies into industrial scale manufacturing.

Building upon the success of the previous initiative, the Office of Future Mobility and Electrification and the Michigan Department of Transportation launched the Michigan Mobility Funding Platform to provide grants to mobility and electrification companies looking to deploy their technology solutions in the state of Michigan. The PlanetM Pilot Grant supports global mobility companies in deploying their technologies throughout Michigan in partnership with Michigan communities. Awarded PlanetM Pilot Grant funds ultimately make it easier, safer and more affordable for people and goods to move around.

First Approach

[171] https://www.michigan.gov/whitmer/0,9309,7-387-90499_90640-533468--,00.html

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733286.

Contact Person	European researchers interested in finding more information regarding Michigan's Office for Future Mobility and Electrification could directly contact Trevor Pawl, Michigan's chief mobility officer, by completing a form available at https://www.michiganbusiness.org/ofme/.
Phone Number	888 522 0103
Internet link	https://www.michiganbusiness.org/ofme/ https://www.planetm.com/test-and-pilot/

4.2.4. Ohio: The 33 Smart Mobility Corridor

https://www.thebetadistrict.com/us-33-smart-mobility-corridor/

The Ohio's 33 Smart Mobility Corridor is a collaborative effort between the Ohio State University, Ohio Department of Transportation (ODOT), the Ohio Department of Public Safety, Wright-Patterson Air Force Base, Ohio State University, Case Western Reserve University, University of Cincinnati, University of Dayton, Wright State University, the Transportation Research Center and the Ohio Turnpike and Infrastructure Commission. This initiative aims to provide an environment to safely test innovative technologies that will change the mobility system in Ohio[172]. The Corridor is a key element of Ohio's Smart Mobility Initiative[173, 174].

First Approach	
Contact Person	European researchers interested in Ohio's Smart Mobility Initiative could contact the relevant officer by filling the form at: https://www.thebetadistrict.com/contact/
Internet link	https://www.thebetadistrict.com/us-33-smart-mobility-corridor/

[172]http://www.truckinginfo.com/channel/fleet-management/news/story/2016/11/ohio-dot-otto-initiate-smart-mobility-corridor.aspx
[173]http://www.33smartcorridor.com/mobility
[174]http://www.cargroup.org/wp-content/uploads/2017/04/CAV_International_Survey_2017_555402_7.pdf

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5 Observations

From the assessment of the US C&AD research community presented above, it is clear that the US is one of the global leaders in C&AD R&D activities. The US is home to numerous leading university research groups, industry-university research centers and industry clusters. The number of citations from authors that conduct research in US university research groups also demonstrates that the US is home to some of the most relevant authors in the field of C&AD.

The analysis of the US research landscape reveals that its research community includes a wide range of different actors that conduct multidisciplinary R&D activities. Thus, the C&AD research community encompasses a joint effort of academia, industry and federal/state entities, which have been working together to develop innovative technologies in the field of C&AD.

In the field of C&AD, partnerships between industry and universities are particularly important due to the need for an interdisciplinary approach and the growing complexity of the C&AD technologies. In this context, in the US the development of industry-university research partnerships has been crucial to exchange knowledge and develop advanced technologies.

As detailed within this research handbook, clusters are also one of the main drivers of R&D activities. The automotive industry recognizes the mutual benefits of establishing partnerships with members from academia in order to exchange knowledge and develop new advanced technologies. In the field of C&AD, it is highly important that academia and industry can work together in developing technologies that can lead to safer, cleaner and more efficient mobility systems. Therefore, in the US there are five industry clusters that stand out particularly for their C&AD R&D activities, with Silicon Valley and Michigan Automotive Cluster being exceptional cases in this research field.

In addition, research networks and professional associations also play a crucial role in fostering interaction between academia, industry and federal/state entities. However, since C&AD is a very recent area and the connection between academia and industry is already fostered by industry clusters and industry–university research centers, there are few US research networks focused on C&AD.

In the US, the C&AD research is highly supported by programs and initiatives from federal and state government entities, such as the DOD, DOE, DOT and the FDOT. Currently, the US government is highly committed to fund cutting-edge research, such as C&AD. The US government aims to leverage the knowledge gained and the technology developed to promote a smarter and safer transportation system, which will be deeply grounded in the cooperation between academia and industry.

Even though, the US government is highly committed in supporting EU-US R&D cooperation it is important to highlight the information related to federal and state funds and grants for European researchers is difficult to find. European researchers interested in US C&AD initiatives and programs often need to contact the program officers to know specific details about international eligibility. In fact, only a few programs and initiatives have specific information available on line about eligibility, which hinders access to information.

As a general statement, the analysis carried out in this research handbook shows there are important EU-US R&D cooperation opportunities in the C&AD field. Both regions consider C&AD as a research

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priority and are highly committed to support research in this field with the aim of developing safer, cleaner and easier mobility systems that truly satisfy the needs of the citizens.

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Annex 1: Examples of Research Fields and Organizations in Thematic Research Areas Related to C&AD

The table below presents further examples of research fields and organizations in the thematic research areas related to C&AD that were identified based on desk research, not through the analysis of paper citations.

Table 4 – Further Examples of Organizations in the Main Thematic Research Areas Related to C&AD

Thematic research areas related to C&AD	Research fields	Example of universities conducting research in the field
Artificial intelligence	Computer Science Robotics Engineering Transportation Automation Control Systems	Carnegie Mellon University University of Michigan Massachusetts institute of technology University of California State University of Florida
Big Data	Computer Science Engineering Transportation Telecommunications Environmental Sciences Ecology	University of Tennessee University of Georgia University of Michigan State University of Florida Clemson university
Cyber-physical systems	Engineering Computer Science Telecommunications Automation Control Systems Transportation	University of California University of Georgia Vanderbilt University University of Nebraska Georgia Southern University
Cybersecurity	Engineering Computer Science Transportation Telecommunications Robotics	University of California Washington State University University of Michigan United States Department of Energy State University of Florida
Wireless Communication	Engineering Computer Science Telecommunications Transportation Automation control systems	University of California University of Georgia State University of Florida Old Dominion University Clemson University

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Thematic research areas related to C&AD	Research fields	Example of universities conducting research in the field
Total	Computer Science Engineering Transportation Telecommunications Robotics	Carnegie Mellon University University of Michigan Massachusetts institute of technology University of California University of Georgia

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Annex 2: Summary of the US Federal and State Funding Initiatives and Programs

The table below summarizes the US Federal and State funding initiatives in the field of C&AD and provides relevant information on how EU researchers could first approach them.

Table 5 Summary of the US Federal and State Funding Initiatives and Programs

Agencies	Programs/ Initiatives	Relevant Research Areas	Contact Info	Internet link
Federal Initiatives and Programs				
NSF		Smart and Autonomous Systems, CPSs and Robust Intelligence	eeinfo@nsf.gov	www.nsf.gov/od/oise/country-list.jsp
	Smart and Connected Communities (S&CC) program	Intelligent Physical Systems: robotic platforms and networked systems that combine computing, sensing, communication and actuation	David Corman dcorman@nsf.gov (703) 292-8754	https://beta.nsf.gov/funding/opportunities/smart-and-connected-communities-scc

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Agencies	Programs/ Initiatives	Relevant Research Areas	Contact Info	Internet link
	NSF's Cyber-Physical Systems (CPS) program	Cyber-Physical Systems	David Corman dcorman@nsf.gov (703) 292-8754	www.nsf.gov/pubs/2017/nsf17529/nsf17529.htm
	NSF's Robust Intelligence (RI) program	Robust Intelligence : AI, computer vision, human language research, robotics, machine learning, computational neuroscience and other related areas	James Donlon jdonlon@nsf.gov (703) 292-8074	www.nsf.gov/staff/sub_div.jsp?org=IIS&orgId=3947&from_org=IIS
DOE	DOE's Energy Efficient Mobility Systems (EEMS) subprogram	Energy efficiency and smart mobility	Contact the point of contact identified in the funding opportunities www.grants.gov/ www.eere-exchange.energy.gov/	https://eere-exchange.energy.gov/
	SuperTruck 3 Initiative	Energy efficient transportation technologies and systems	Contact the point of contact identified in the funding opportunities www.grants.gov/ www.eere-exchange.energy.gov/ eere-exchangesupport@hq.doe.gov DE-FOA-0002450@netl.doe.gov	https://eere-exchange.energy.gov/Default.aspx#FoaIdbba83da0-9b58-4d26-8c6a-4a36230aed4f
	Low Greenhouse Gas Vehicle Technologies Initiative	Energy efficient transportation technologies and systems	Contact the point of contact identified in the funding opportunities www.grants.gov/ www.eere-exchange.energy.gov/	https://eere-exchange.energy.gov/Default.aspx#FoaIdbba83da0-9b58-4d26-8c6a-4a36230aed4f

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Agencies	Programs/ Initiatives	Relevant Research Areas	Contact Info	Internet link
			EERE-ExchangeSupport@hq.doe.gov DE-FOA-0002475@netl.doe.gov	
DOD	DARPA Explainable Artificial Intelligence (XAI) Program	AI and machine learning	David Gunning XAI@darpa.mil	www.darpa.mil/attachments/DARPA-BAA-16-53.pdf
	Human Interaction with Autonomous Systems Program	Human Interaction and Autonomous Systems	Tom McKenna tom.mckenna@navy.mil (703) 696-5031	www.onr.navy.mil/en/Science-Technology/Departments/Code-34/All-Programs/human-bioengineered-systems-341/Human-Robot-Interaction
	Cyber Security and Complex Software Systems Program	Information Assurance of Cyber-Physical Systems; Trusted Network Computing; Secure Information Management, Sharing and Interaction; and Principles for Correctness and Security Properties	Sukarno Mertoguno sukarno.mertoguno@navy.mil (703) 696-5031	www.onr.navy.mil/Science-Technology/Departments/Code-31/All-Programs/311-Mathematics-Computers-Research/Cyber-Security-Software
	Distributive and Collaborative Intelligent Systems	Intelligent Vehicles, Intelligent Infrastructure and the Development of an Intelligent Transportation System	Brett Pikarski brett.h.piekarski.civ@mail.mil (301) 394-1263	https://www.dcist.org/

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Agencies	Programs/ Initiatives	Relevant Research Areas	Contact Info	Internet link
DOT	Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD)	Mobility safety, efficiency, system performance and infrastructure	-	www.fhwa.dot.gov/fastact/nofo_atcmtd_20160325.pdf
	Connected Vehicle Pilot Deployment Program	Advanced mobile and roadside technologies	Katherine K. Hartman Kate.Hartman@dot.gov (202) 366-2742	www.its.dot.gov/pilots/pilots_overview.htm
	FHWA Exploratory Advanced Research (EAR) Program	Exploratory Advanced Research with a high remuneration potential	David E. Kuehn david.kuehn@dot.gov (202) 493-3414	www.fhwa.dot.gov/advancedresearch/about.cfm#gen
	ITS Joint Program Office (ITS JPO)	Intelligent Vehicles, Intelligent Infrastructure and the Development of an Intelligent Transportation System	Kevin Dopart Kevin.Dopart@dot.gov (202) 366-5004	www.its.dot.gov/automated_vehicle/
State Initiatives and Programs				
CDOT	Colorado: Connected & Autonomous Technology Program	Energy efficiency and smart mobility	Ashley Nylen ashley.nylen@state.co.us	www.codot.gov/programs/research
FDOT	Florida Automated Vehicles (FAV) program	Educate the public for the deployment of C&AD technologies	fdot.servicedesk@dot.state.fl.us	www.fdot.gov/research/

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Agencies	Programs/ Initiatives	Relevant Research Areas	Contact Info	Internet link
			(850) 414-4616	
MOFT	Michigan's Office for Future Mobility and Electrification	Energy efficiency and smart mobility	Trevor Pawl https://www.michiganbusiness.org/ofme/ 888 522 0103	https://www.michiganbusiness.org/ofme/ https://www.planetm.com/test-and-pilot/
ODOT	The 33 Smart Mobility Corridor	Energy efficiency and smart mobility	https://www.thebetadistrict.com/contact/	https://www.thebetadistrict.com/us-33-smart-mobility-corridor/

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Annex 3: Summary of the collaborative EU-USA H2020 projects within topics related to transportation and connected & automated driving

Project Title	Project Acronym	Topic	CORDIS link	Topic Code
Overall Air Transport System Vehicle Scenarios	OASyS	Overall Air Transport System Vehicle Scenarios	http://cordis.europa.eu/project/id/864521	JTI-CS2-2018-CfP09-TE2-01-08 MG-2-14-2020
Further Understanding Related to Transport limitations at High current density towards future ElectRodes for Fuel Cells	FURTHER-FC	Towards a better understanding of charge, mass and heat transports in new generation PEMFC MEA for automotive applications	http://cordis.europa.eu/project/id/875025	FCH-01-4-2019
Investigating Mechanisms and Models Predictive of Accessibility of Therapeutics (IM2PACT) Into The Brain	IM2PACT	Discovery and characterisation of blood-brain barrier targets and transport mechanisms for brain delivery of therapeutics to treat neurodegenerative & metabolic diseases	http://cordis.europa.eu/project/id/807015	IMI2-2017-12-06
Innovative photocatalysts integrated in flow photoreactor systems for direct CO2 and H2O conversion into solar fuels	NEFERTITI	International Cooperation with USA and/or China on alternative renewable fuels from sunlight for energy, transport and chemical storage	http://cordis.europa.eu/project/id/101022202	LC-SC3-RES-3-2020
International cooperation for selective conversion of CO2 into METHAnol under SOLar light	METHASOL	International Cooperation with USA and/or China on alternative renewable fuels from sunlight for energy, transport and chemical storage	http://cordis.europa.eu/project/id/101022649	LC-SC3-RES-3-2020
SIMULATOR OF BEHAVIOURAL ASPECTS FOR SAFER TRANSPORT	SimuSafe	Behavioural aspects for safer transport	http://cordis.europa.eu/project/id/723386	MG-3.5-2016
Enhanced Physical Internet-Compatible Earth-frieNdly freight Transportation answER	ePIcenter	InCo Flagship on Integrated multimodal, low-emission freight transport systems and logistics	http://cordis.europa.eu/project/id/861584	MG-2-9-2019
WORKFORCE EUROPE - TRANSFORMATION AGENDA FOR TRANSPORT AUTOMATION	WE-TRANSFORM	The effects of automation on the transport labour force, future working conditions and skills requirements	http://cordis.europa.eu/project/id/101006900	MG-2-14-2020
Trustable architectures with acceptable residual risk for the electric, connected and automated cars	ArchitectECA2030	ARCHITECTURES, COMPONENTS, AND SYSTEMS FOR VALIDATION/SIMULATION OF CONNECTED AUTOMATED VEHICLES	http://cordis.europa.eu/project/id/877539	ECSEL-RIA-2019-2-Special-Topic-1

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