Mobile Connected and Automated Medical Care System

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Description of the problem, its importance to the State of Alabama and how it is generalizable to other States, the U.S. and the world

The efficiency of medical treatment of emergency patients (both civilians and warfighters) in a hospital health care system directly depends on an incoming patient's health condition, which is predetermined by the (i) medical care and lifesaving equipment available in an ambulance vehicle, (ii) qualification of emergency medical technicians (EMTs) and paramedics, and (iii) ability of the ambulance vehicle to provide conditions for a medical treatment during the patient transportation.

The above-listed three items are *fundamental cross-disciplinary problems* that cannot be completely addressed and solved within today's paradigm of the ambulance vehicle as a *single lifesaving rescue/evacuation transportation mean*. Indeed, the main purpose of a paramedic team is to save life of a person rather than to provide a medical care in a remote location (far away from a hospital) or during the transportation phase to the hospital. With all due respect to EMTs and paramedics' lifesaving work, they are not expected to provide medical care, procedures, surgeries, etc. within the existing paradigm of the ambulance vehicle. There is no access to the patient medical database available to the paramedic teams, and hospital-based doctors are not a part of the paramedic team while the patient is being transported in the ambulance vehicle.

The medical equipment and internal design of ambulances was formed in accordance with the lifesaving paradigm. However, the equipment is not suitable for providing medical care when an ambulance is far away from a hospital or a medical center, i.e., in a rural area or in a war region.

Today's ambulances have been designed and built on conventional vehicle platforms, which conceptual mechanical design cannot exploit advances in recent electronic connectivity and automation technologies. Ambulance vehicle safety has become questionable. According to NHTSA's analysis based on the data from the past 20 years [1], the nation averages 29 fatal crashes involving an ambulance each year, resulting in an average of 33 fatalities annually. NHTSA estimates that an average of 1,500 ambulance crashes per year result in injury, with 46% of injuries occurring among people inside the ambulance at the time of the collision. Additionally, of the 45 providers in the patient compartment at the time of the crash, only 7 (16%) were wearing a seat belt at the time of the crash, meaning 38 (84%) were unrestrained [1]. The latter-referred data witnesses the fact that ambulance vehicles do not provide safe conditions for the paramedics who have to treat their patients while the vehicle is moving.

This project will solve the three cross-disciplinary problems and radically improve the health care system efficiency by shifting the paradigm of the ambulance vehicle from a single lifesaving rescue/evacuation transportation mean to the paradigm of a *mobile connected and automated medical care system*. The proposed paradigm is novel and has never been researched before.

This cross-disciplinary project will strengthen collaboration between the UAB SOE, CAS, and SOM. UAB will enhance its role as the primary health care provider in Birmingham and the State of Alabama by initiating and implementing the novel mobile medical care in cooperation with industry in Alabama and the U.S. The project will bring UAB yet to another level of national and

international recognition, as the University will be the only leader of the proposed novel direction in health care in the nation and worldwide.

Desired outcomes and the conceptualization of the plan of work to achieve them

As the main outcome, a *demonstrator of a mobile connected and automated medical care system* for either civilian or combat conditions will be researched, designed, developed, and tested. The systems approach will be applied to establish a novel transformative and transdisciplinary framework with the purpose to converge recent research areas of vehicle subsystem design and engineering, advanced medical care and precision medicine, wearable robots and robotic assisting medical devices, and socially cognizant, secure and safe connectivity and autonomy of the vehicle ambulance and the hospital-based medical care system.

Vehicle Engineering. Dynamic couplings and interference of vehicle subsystems, intrinsic heterogeneity, and necessary parallelism of processes and their concurrency and sensitivity in *vehicle cyber* and *physical subsystems* are main challenges in *vehicle design* and *application* of *artificial intelligence-based decision making* and *controls*. The listed challenges conceptually limit fundamental advancements in vehicles by allowing for only incremental improvements in vehicle dynamics, performance, efficiency and safety. These problems will be addressed by applying a module-based approach to vehicle design to establish agile interaction between cyber-physical domains of vehicle subsystems. The patient compartment (medical care unit) of the vehicle prototype will be designed based requirements to medical treatment and intervention technologies in a harmonization with vehicle motion characteristics and vehicle subsystem control.

Advanced Medical Care and Precision Medicine. Recent advancements in *medical treatment* and *intervention technologies* will be analyzed for the purpose of their optimal operation in the mobile medical care system. *Personal identification* of patients and their *medical history data* will be integrated with an *emerging precision medicine* approach to account the individual human variability while conducting on-board medical test works, treatment, etc. The *diagnosis*, *necessary on-board treatment* and *interventions* will be implemented remotely with a networking medical doctors and scientists in the country and, potentially, in the world. Special requirements to professional experience and skills of the ambulance team and networking medical and scientific personnel will be developed in the project.

Wearable Robots and Robotic Assisting Medical Devices. Wearable robots will be designed for assisting the ambulance team with treatment and intervention procedures in the moving vehicle. The Vehicle - Wearable Robot - Team Member - Patient system will be studied and designed for human-robot cognitive/physical interaction, network communication, and for a safe functioning of the ambulance team in the moving vehicle. Robotic assisting medical devices will be engaged in medical interventions with both remote and on-board control by the hospital-based doctors and ambulance team.

Socially Cognizant, Secure/Safe Connectivity and Autonomy of Ambulance-Hospital System. A novel Connectivity and Autonomy of Ambulance-Hospital System framework will be designed and tested in the project while addressing practical big data operation and regulatory issues, cyber-physical security, emergency preparedness, and ethical dilemmas. Specifically, the project will contribute to levels 3 and 4 of the NHTSA autonomy scale by providing a secure/safe framework for advanced autonomous vehicle platforms integrated with novel human-in-the-loop controls. Autonomy-in-the-loop as an extension to advanced driver assistant systems will be researched and implemented to increase safety of ambulance vehicles by contributing to real-time decision making of cyber-physical systems with humans that execute decisions only when dictated by the autonomous system. Mitigating techniques to ensure safety and security at the various cognitive

levels of adversaries will be integrated in the mobile connected and automated medical care system (including the vehicle and the hospital).

List of potential team members (individuals and organizations) from inside and outside UAB

Organization	Individual	Potential Participation
Inside UAB		
School of Engineering	Dept. of ME, EITD, ECE, BME, CE	Confirmed
College of Arts and Sciences	Dr. Despina Stavrinos, Phycology Dr. Ragib Hasan, Computer and Information Sciences Dr. Chengcui Zhang, Computer and Information Sciences	Confirmed
School of Medicine	Dr. Pankaj Dangle, Urology	Confirmed
Outside UAB		
US Army RDECOM-TARDEC	Dr. David Gorsich, Chief Scientist and Army ST (Ground Systems)	Confirmed
Oak Ridge National Laboratory	Dr. Xin Sun, Director Energy and Transportation Science Division	Confirmed
Ford Motor Company	Dr. Saeed Barbat, Executive Technical Leader for Safety	In progress
Ford Motor Company	Dr. Jianbo Lu, Technical Expert/Manager Role, Autonomous Vehicle Group	Confirmed
AVL Powertrain	Dr. Hanlong Yang, Chief Engineer	Confirmed
Priority Ambulance, National Association of Emergency Medical Technicians	Dennis Rowe, Director of Business Integration President, National Association of Emergency Medical Technicians	In progress
Southern Company Services	Pradeep K. Vitta, Energy End Use R&D Manager Blair Farley, Researcher	Confirmed
Altec	Chris Harned	In progress
Virginia Tech	Dr. Kyriakos Vamvoudakis	Confirmed
Georgia Tech	Dr. Wassim Haddad	Confirmed
New Your University	Dr. Zhong-Ping Jiang	Confirmed
University of Cassino, Italy	Dr. Marco Ceccarelli	Confirmed
KTH, Sweden	Dr. Karl Henrik Johansson	In progress

Reference:

1. A National Perspective on Ambulance Crashes and Safety, Guidance from the National Highway Traffic Safety Administration on ambulance safety for patients and providers, September 2015.