



Developing a Research Roadmap for Smart Fire Fighting

CHAPTER OUTLINE

Last Updated: 12 April 2014

The purpose of this “Chapter Outline” document is to provide the details for the content and organization of a roadmap that will address research in support of smart fire fighting. This will be the primary deliverable for the project on “Developing a Research Roadmap for Smart Fire Fighting.”

This document is composed of the following five sections:

- 1) Section 1: Chapter Structure page 2
- 2) Section 2: Terminology page 4
- 3) Section 3: Chapter Scopes page 5
- 4) Section 4) Notional CPS Reference Architecture page 6
- 5) Section 5: Summary of CPS Levels and Layers page 8

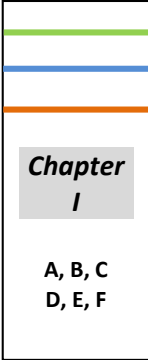
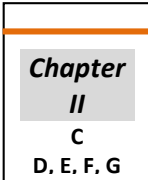
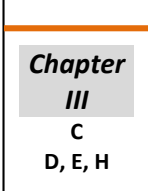
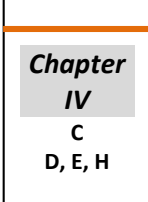
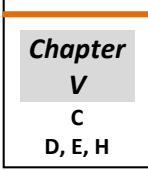
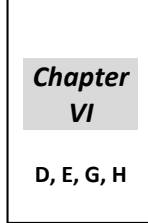
Section 1 contains the primary summary information, and it is supported by the additional information included in sections 2 through 5. The Section 1 information provides a comprehensive overview of the structure and organization of the proposed roadmap, with the key topics indicated in the outline on the left side of pages 2 through 4, while the proposed roadmap chapters are indicated on the right hand side of pages 2 through 4.

There are currently 11 proposed core chapters, along with an opening and concluding chapter (i.e., Chapters I and XIII). On pages 2 through 4, the chapters are identified by the boxes on the left side of the pages. This also includes clarification of the CPS (cyber physical system) levels and layers from the Notional CPS Reference Architecture, which is described in sections 4 and 5. The CPS Levels are designated by a specific color coding and the letters A through C, and the CPS Layers are designated by a different color coding and the letters D through H. This is intended to clarify the CPS architecture as it is meshed with the proposed topic areas of smart fire fighting.

SECTION 1: CHAPTER STRUCTURE

Topics

Chapters

<ol style="list-style-type: none"> 1. Background and Vision <ol style="list-style-type: none"> 1.1. Roadmap Scope and Purpose 1.2. Overview of the Current State and Future Trends <ol style="list-style-type: none"> 1.2.1.U.S. Fire Problem <ol style="list-style-type: none"> 1.2.1.1. National Losses and Costs 1.2.1.2. Practical Challenges Facing Fire Fighting: Before During and After an Incident 1.2.1.3. Requirements/ Limitations of Current State (Equip, Apparatus, Operations, etc) 1.2.2.Demographics (Fire Service, Building, and People) 1.2.3.Technological Landscape 1.2.4.Cyber Physical Systems 1.3. Vision of Smart Fire Fighting 	
<ol style="list-style-type: none"> 2. Communication (Gathering of Data) <ol style="list-style-type: none"> 2.1. Communication Technology & Delivery Methods <ol style="list-style-type: none"> 2.1.1.Personal Area Network (on-board fire fighting PPE and ESE) 2.1.2.Team/Unit (fire fighters and officers) 2.1.3.Fireground Incident Command (incident command and officers/fire fighters) 2.1.4.Inter-Jurisdiction (between communities for large scale events) 2.2. Sensors <ol style="list-style-type: none"> 2.2.1.PPE: Personal Protective Equipment (ESE, i.e., on-board the fire fighter) <ol style="list-style-type: none"> 2.2.1.1. Environmental Monitoring 2.2.1.2. Physiological Monitoring 2.2.1.3. Sensory Support 2.2.1.4. Tracking/Location 2.2.1.5. Electronic Textiles 2.2.2.Mobile <ol style="list-style-type: none"> 2.2.2.1. Portable equipment (mobile equipment not on-board the fire fighter) 2.2.2.2. Land Based Vehicles 2.2.2.3. Air and Water Craft 2.2.2.4. Robotics 2.2.2.5. UAV/Satellite 2.2.3.Stationary <ol style="list-style-type: none"> 2.2.3.1. Building 2.2.3.2. Occupants and General Public 2.2.3.3. Public and Utility-Services Infrastructure 2.2.3.4. Outdoor 2.3. Data Collections 2.4. Existing Databases <ol style="list-style-type: none"> 2.4.1.1. Fire Loss Records (NFIRS, NFORS, Injury data, Insurance) 2.4.1.2. Fire Fighting Resources (Computer Aided Dispatch) 2.4.1.3. Building Information Management (internal to building) 2.4.1.4. Infrastructure (e.g., public utilities, traffic, road conditions) 2.4.1.5. Outdoor (weather, topography, vegetation, building location) 2.4.2.Trends for Future Databases 	    

3. Computation (Processing of Data)

3.1. Hardware/Software

3.1.1. Input/output Protocols

3.1.2. Interface Standards

3.1.3. Data Representation

3.1.4. Security/Privacy

3.1.5. Component Attributes

3.1.5.1. Reliability

3.1.5.2. Operability

3.1.5.3. Maintainability

3.1.5.4. Durability

3.1.5.5. Availability

3.1.5.6. Stability

3.2. Compatibility, Integration, and Interoperability

3.2.1. Inter-Component Communication

3.2.2. Component Non-Interference

3.2.3. Centralized Power Supply

3.2.4. Data Analytics

3.3. Real-time Data Analytics

3.3.1. Data Mining

3.3.2. Big Data Applications

3.4. Knowledge Based Fire Fighter Decision-Making and Analysis (NFPA 1500 Risk Management)

3.4.1. Modeling

3.4.2. Inverse Modeling/Data Assimilation

3.4.3. Algorithms

3.5. Database Analytics

Chapter VII

B
D, E, G, H

Chapter VIII

B
D, E, G, H

4. Targeted Decision Making (Use of Data)

4.1. Fire Service Data User Applications

4.1.1. Pre-Emergency and Post-Event

4.1.1.1. Inspectors and Enforcers

4.1.1.2. Pre-Planning

4.1.1.3. Training and Education

4.1.1.3.1. Pre-Fire

4.1.1.3.2. Post-Fire

4.1.1.3.3. Post Fire Investigators

4.1.2. Event

4.1.2.1. Structural (building and vehicular)

4.1.2.2. Wildland (wildfire and WUI)

4.1.2.3. Special (proximity, technical rescue, hazmat, EMS)

Chapter IX

A
D, F

Chapter X

A
D, E, F, G, H

- 4.2. Non-Fire Fighter Data User Applications
 - 4.2.1. Call Processing Centers and Emergency Point of Contact (911 Centers)
 - 4.2.2. Primary and Secondary Emergency Receivers
 - 4.2.2.1. Hospitals
 - 4.2.2.2. Medical Examiner
 - 4.2.2.3. Environmental Cleanup / Salvage
 - 4.2.2.4. Insurance
 - 4.2.3. General Public and Building Occupants
 - 4.2.4. Governmental Administration
- 4.3. User Interface Delivery Methods
 - 4.3.1. Hand-held Devices
 - 4.3.2. Heads-up Displays
 - 4.3.3. Augmented Reality

**Chapter
XI**

A
D, E, F

**Chapter
XII**

D, E, F, G, H

5. Summary Observations and Recommendation

- 5.1. Summary Observations
- 5.2. Recommendations for Future Research
 - 5.2.1. Prioritized List
- 5.3. Real and Hypothetical Case Study Examples

**Chapter
XIII**

SECTION 2: TERMINOLOGY

<p>CAD – Computer Aided Dispatch</p> <p>CPS – Cyber Physical Systems</p> <p>EMS – Emergency Medical Service</p> <p>ESE – Electronic Safety Equipment</p> <p>HazMat – Hazardous Materials</p> <p>PPE – Personal Protective Equipment</p>	<p>NFIRS – National Fire Incident Reporting System</p> <p>NFPA – National Fire Protection Association</p> <p>NFORS – National Fire Operations Reporting System</p> <p>SFF – Smart Fire Fighting</p> <p>UAV – Unmanned Aerial Vehicles</p> <p>WUI – Wildland-Urban Interface</p>
---	---

SECTION 3: CHAPTER SCOPES

Chapter	Description	Chapter Scope
<i>I</i>	Roadmap Scope and Purpose	Scope: Overview of the current state and future trends, along with clarifying the vision of smart fire fighting.
<i>II</i>	Communication Technology & Delivery Methods	Scope: Gathering of data based on communication technology and delivery methods, including personal area networks on-board fire fighters, teams and units, fireground incident command, and inter-jurisdiction.
<i>III</i>	Sensors: PPE	Scope: Sensor technology involving Personal Protective Equipment (PPE), i.e., fire fighter on-board Electronic Safety Equipment (ESE that includes but is not limited to: environmental monitoring; physiological monitoring; sensory support; tracking/location; and electronic textiles
<i>IV</i>	Sensors: Mobile	Scope: Sensor technology involving mobile fire fighting, including but not limited to: portable equipment (mobile equipment not on-board the fire fighter); land based vehicles' air and water craft; robotics; and UAV/satellites.
<i>V</i>	Sensors: Stationary	Scope: Sensor technology involving stationary technology; including buildings; occupants and the general public; public and utility-services infrastructure; and outdoors.
<i>VI</i>	Data Collections	Scope: Existing database collections (e.g., fire loss records, fire fighting resources, building information management, building supporting infrastructure, outdoor, etc.), as well as trends for future databases.
<i>VII</i>	Hardware/Software and Interoperability	Scope: Computation of data involving hardware and software, including issues relating to compatibility, integration and interoperability.
<i>VIII</i>	Data Analytics	Scope: Real-time data analytics such as data mining and big data applications, as well as knowledge based fire fighter decision-making and analysis (e.g., NFPA 1500 risk management concepts), such as modeling, inverse modeling/data assimilation, algorithms, and database analytics.
<i>IX</i>	Fire Service Data User Applications: Pre-Emergency and Post-Event	Scope: Fire service data user applications that are focused on pre-event and post event, including but not limited to: inspectors and enforcers, pre-planning, training and education, and fire investigation.
<i>X</i>	Fire Service Data User Applications: Event	Scope: Fire service data user applications that are focused on the fireground even, including but not limited to: buildings, transportation systems, wildland, and special applications (e.g., proximity, technical rescue, hazmat, EMS, etc.).
<i>XI</i>	Non-Fire Fighter Data User Applications	Scope: User applications that involve data for other than fire fighters, such as call processing centers (e.g., 911 centers), primary and secondary emergency receivers (e.g., hospitals, medical examiners, environmental cleanup, salvage, insurance), general public and building occupants, and governmental administration.
<i>XII</i>	User Interface Delivery Methods	Scope: User interface delivery methods such as hand-held devices, heads-up displays, and augmented reality.
<i>XIII</i>	Summary Observations	Scope: Summary observations, prioritized recommendations for future research, and real and hypothetical case study examples.

SECTION 4: NOTIONAL CPS REFERENCE ARCHITECTURE

4a: CPS Levels

A) Business and User Goals- specific, measurable, action-oriented, realistic, and timely goals for lines of business and users to reach organizational mission objectives

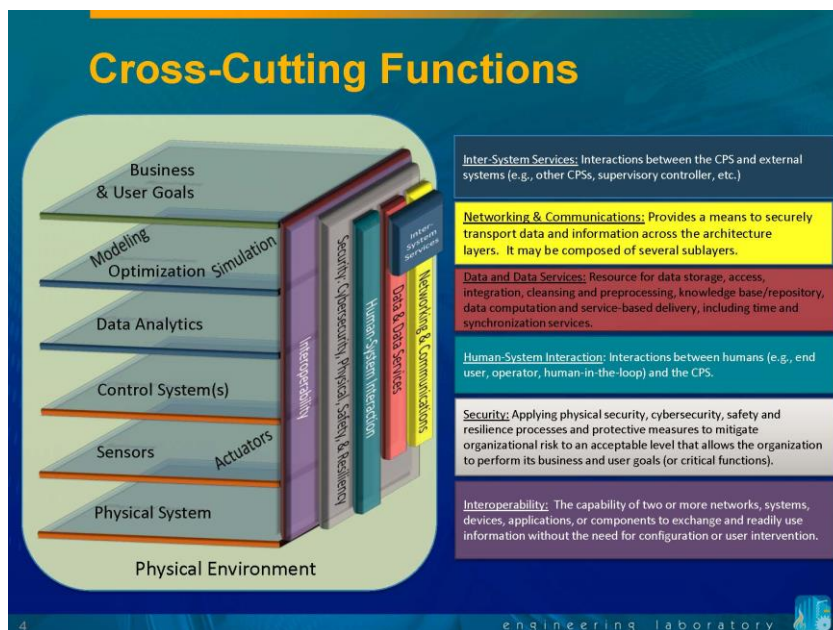
B1) Optimization (Modeling and Simulation)- Develops and maintains dynamic, performance-based, computational models. These models use decisions on diagnosis and prognosis from the data analytics as input and determine whether business goals are met.

B2) Data Analytics-Assimilate, filter, and process data from different components for pattern recognition (normal or abnormal), predictive analytics and intelligent decision-making, extract knowledge using machine learning and data mining, and visual analytics for use by controller, users, cybersecurity stack and other components.

C1) Control Systems - Control system(s), which may be distributed, acquire data from sensors, perform local processing, and control actuators to produce a prescribed state of the physical system in the physical environment.

C2) Sensors - Sensors acquire data from the physical system and transmit the information to storage, measurement and/or control device(s). Actuators receive signals from a control device and act on the physical system. Sensors and actuators may be smart and/or distributed.

C3) Physical System-The engineered physical system that interacts with sensors and actuators and operates in the physical environment. The physical system is ideally co-designed along with the cyber-system to optimize the overall system. In some cases the physical system is an existing legacy system into which cyber elements are added.



4b: CPS Layers

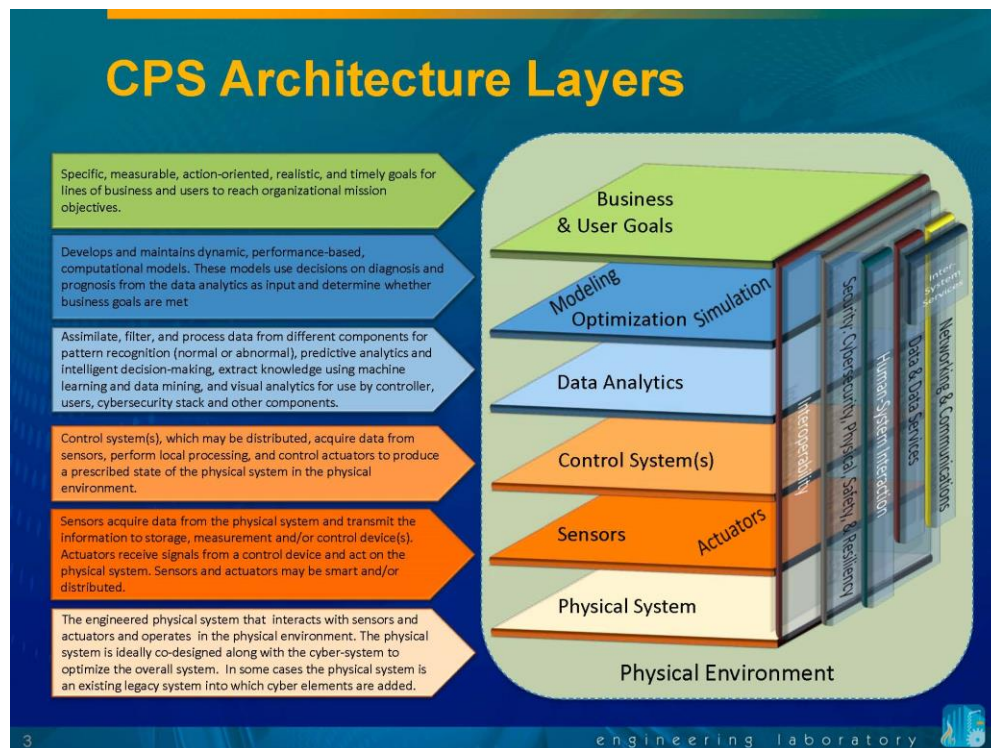
D) Interoperability - The capability of two or more networks, systems, devices, applications, or components to exchange and readily use information without the need for configuration or user intervention.

E) Security: Cybersecurity, Physical, Safety, & Resiliency- Applying physical security, cybersecurity, safety and resilience processes and protective measures to mitigate organizational risk to an acceptable level that allows the organization to perform its business and user goals (or critical functions)

F) Human-System Interaction- Interactions between humans (e.g., end user, operator, human-in-the-loop) and the CPS.

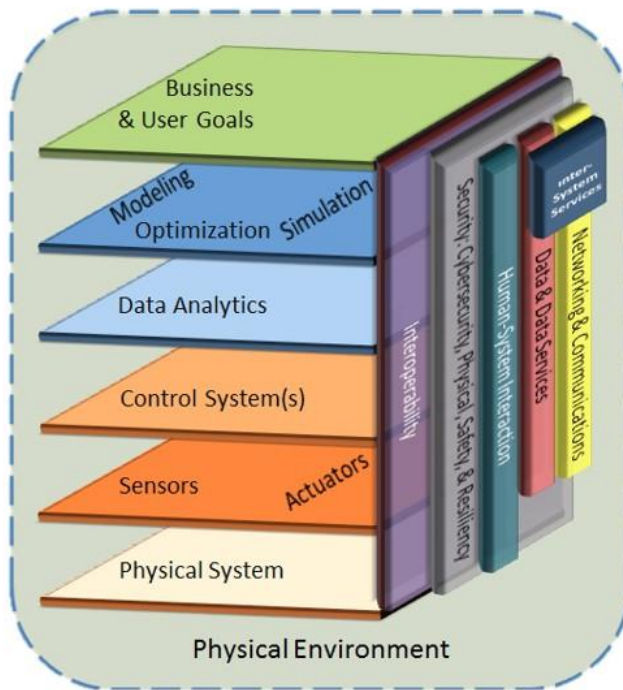
G) Networking and Communications-Provides a means to securely transport data and information across the architecture layers. It may be composed of several sublayers.

H) Data and Data Services- Resource for data storage, access, integration, cleansing and preprocessing, knowledge base/repository, data computation and service-based delivery, including time and synchronization services



SECTION 5: SUMMARY OF CPS LEVELS AND LAYERS

Notional CPS Reference Architecture (draft, work in progress, notional, draft, ...)



- Functional, multi-stack architecture
- All layers should be co-designed in the context of the Physical Environment
- Management function, not depicted, provides oversight and ensures coordination and composability

1