**Title:** ULS Systems Research Roadmap

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**Abstract:**
Roadmap Intent

Help evaluate the ULS systems relevance of existing or planned research

- The roadmap structure explicitly shows a ULS system perspective

Prioritize research funding

- The roadmap provides a basis for determining which research is most critical/relevant/impactful for achieving a future ULS systems capability

Framework for incorporating additional ULS systems research

Motivate Research

- The roadmap shows how an individual research initiative supports one or more ULS-system technical challenges

Put Research in Context
The Roadmap Root: A Warfighter Capability

The ULS System report mentioned six capabilities needed by the DoD and the roadmap combines two of them (C1/C6) into a single capability to show research relevance to desired military capabilities.

- **Common Relevant Operational Picture (CROP):** Maintain coherent common operating picture
  - across echelons, services, and coalitions in a mix of ultra-large-scale environments (C1)
  - applying local context to global information sources to ensure use of the right data any time, any place, for any mission (C6)
A Needed Warfighter Capability

Common Relevant Operational Picture: Maintain coherent common operating picture by rapidly collecting, processing, disseminating, and protecting information spanning echelons, services, and coalitions across a mix of ultra-large-scale environments. Apply local context to global information sources to ensure use of the right data any time, any place, for any mission.
Technical Observations

Common Relevant Operational Picture: Maintain coherent common operating picture by rapidly collecting, processing, disseminating, and protecting information spanning echelons, services, and coalitions across a mix of ultra-large-scale environments. Apply local context to global information sources to ensure use of the right data any time, any place, for any mission.

- Different users have different info needs based on their role and context
- User needs for info change dynamically
- System connectivity and info flow changes dynamically
- People will (mis)use the system in unexpected ways, stressing HW and SW
- CROP capability evolves non-uniformly in its structure, components, and uses
Roadmap Example

Observation

Different users have different info needs based on their role and context.
Users are developers, i.e., they can augment the system to fit their needs.
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User Customization

Tech challenge:
Provide users with the ability to manipulate and customize info contained in the CROP.

Feed user needs back to a development group, who creates/deploy changes.

Research objective 2
Support user content customizations that can be disseminated to others with similar needs, who then develop them further.

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Augmented Roadmap Example

- CROP capability evolves non-uniformly in its structure, components, and uses.
  - Manage differences rather than eliminate them.
- Different users have different info needs based on their role and context.
  - Users are developers, i.e., they can augment the system to fit their needs.
- Research objective 1: Ensure system stability and QoS as components and usage change.
  - Tech challenge: Provide users with the ability to manipulate and customize info contained in the CROP.
  - Feed user needs back to a development group, who creates/deploys changes.
- User Customization
- Tech challenge: Propagate changes robustly, despite differences in deployed configurations.
  - Assume that knowledge about deployed configurations is accurate.
- Change Propagation
- Research objective 2: Support user content customizations that can be disseminated to others with similar needs, who then develop them further.

Different users have different info needs based on their role and context.
Research objective 1
Ensure system stability and QoS as components and usage changes

6.5.3
Evolutionary Configuration and Deployment

6.6.4
Enforcing Quality Attributes

Research Topic from ULS Systems Report
6.1 Research

Research objective 1
Ensure system stability and QoS as components and usage changes

6.5.3 Evolutionary Configuration and Deployment

6.6.4 Enforcing Quality Attributes

6.5.6.4
Investigate certification techniques that can ensure adaptive systems only operate within safe, correct, and stable configurations

6.5.6.4
Develop models/algorithms/tools that allow validating key functional properties before and during SW updates

6.5.6.4
Determine how to allow user-defined capability to dynamically interact with existing ontologies and user interfaces
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6.5.3
Provide ability for users to build their own, localized ontologies (perhaps as part of Army’s Development Network)

6.5.3
Implement SOA so users can build their own services and so service priorities/performance can be tracked across the enterprise

6.2/3 Research
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Research objective 2
Support user content customizations that can be disseminated to others with similar needs, who then develop them further

6.1.4 Fostering Non-Competitive Social Collaboration

6.1.4/6.6.4
Produce a variety of non-competitive development models relevant to the types of adaptations needed for the CROP while ensuring that these development models can achieve the level of needed quality.
Research objective 1
Ensure system stability and QoS as components and usage changes

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Evolutionary Configuration and Deployment

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Roadmap Structure and Development Process

Start with: a needed ULS system **capability**

Make: **Observations** about this capability

- Example: user needs change dynamically

Use: ULS systems **perspective** (contrasted with conventional approach)

Identify: **Technical challenge** (related to ULS systems perspective)

- Contrast with the “usual” technical challenge

Restate challenge as: **Research objective**

Cite: ULS Systems report **Research Topic**

Define **Research Initiatives**: Several supporting each research objective
Incentivize User

CROP capability evolves non-uniformly in its structure, components, and uses

Different users have different info needs based on their role and context

Manage differences rather than eliminate them

Exploit self-interest rather than overriding it

Tech challenge: Achieve globally appropriate user/system performance while exploiting competitive self-interested behavior

Determine optimal behavior and train people to behave optimally

Research objective 3
Incentivize globally appropriate user behavior by providing rules that encourage appropriate system use
Automatic System Adaptation

User needs for info change dynamically

System connectivity and info flow changes dynamically

Automated adaptation rather than manual intervention to deal with failures and differing operational conditions

Automatic System Adaptation

Tech challenge: Automatically adapt the system to meet high priority user needs despite changes in needs, priorities, and system connectivity

As needs change, commission changes to be implemented by a development group

Research objective 4
Dynamic distributed resource allocation that finds an optimal balance among competing needs
User Relevance and Robustness

Research objective 5
Anticipate user needs in tactical environments with limited resources, provide appropriate information to those users, and learn needs of varying classes of users.

Automated adaptation rather than manual intervention to deal with failures and differing operational conditions.

People will (mis)use the system in unexpected ways, stressing HW and SW.

Robust System

Tech challenge:
Dynamically adjust info offered as the warfighter’s tasks, context, and network connectivity change over time.

Predetermine the info to be transmitted.

Tech challenge:
Design systems to be robust against unlikely usage and operating conditions.

Focus on functionality and normal usage.

User-Relevant Info

System connectivity and info flow changes dynamically.

Failures are normal, i.e., because of scale, even unlikely events will occur.

User needs for info change dynamically.
ULS Systems Research Topics In/Not In Roadmap

6.1.1 Context-Aware Assistive Computing
6.1.2 Understanding Users and Their Contexts
6.1.3 Modeling Users and User Communities
6.1.4 Fostering Non-Competitive Social Collaboration
6.1.5 Longevity
6.2.1 Algorithmic Mechanism Design
6.2.2 Metaheuristics in Software Engineering
6.2.3 Digital Evolution
6.3.1 Design of All Levels
6.3.2 Design Spaces and Design Rules
6.3.3 Harnessing Economics to Promote Good Design
6.3.4 Design Representation/Analysis
6.3.5 Assimilation
6.3.6 Determining and Managing Requirements
6.4.1 Expressive Representation Languages
6.4.2 Scaled-Up Specification, Verification, and Certification
6.4.3 Computational Engineering for Analysis and Design
6.5.1 Decentralized Production Management
6.5.2 View-Based Evolution
6.5.3 Evolutionary Configuration and Deployment
6.5.4 In Situ Control and Adaptation
6.6.1 Robustness, Adaptation, and Quality Attributes
6.6.2 Scale and Composition of Quality Attributes
6.6.3 Understanding People-Centric Qual. Attr.
6.6.4 Enforcing Quality Requirements
6.6.5 Security, Trust, and Resiliency
6.6.6 Engineering Management at Ultra-Large Scales
6.7.1 Policy Definition for ULS Systems
6.7.2 Fast Acquisition for ULS Systems
6.7.3 Management of ULS Systems
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