Developing a Model Based Systems Engineering Architecture for Defense Wearable Technology

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Monitoring Operators in Stressing Conditions

High consequence for poor performance, both physically and cognitively

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Commercially Available Wearable Monitoring has Shortcomings for Military Use

Proprietary algorithms…

Not secure…

Not integrated…
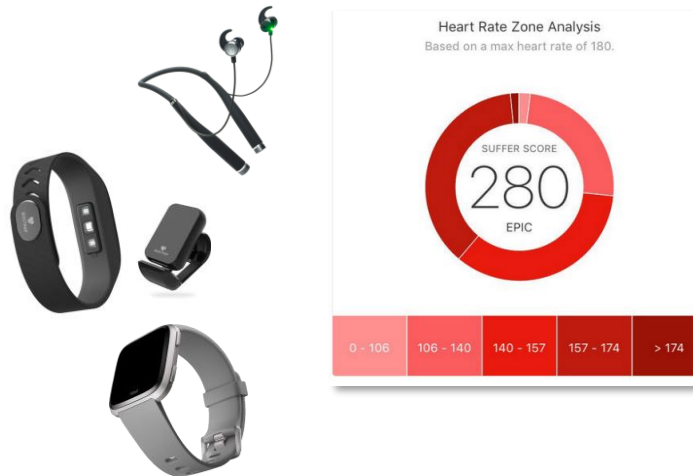
… Not trained against military activities

… For use in military systems

… For open architecture capability

https://news.nike.com/news/what-is-nikefuel

Heart Rate Zone Analysis
Based on a max heart rate of 180.

SUFFER SCORE
280
EPIC

| 0 - 106 | 106 - 140 | 140 - 157 | 157 - 174 | > 174 |

S/N 0291

https://twitter.com/strava/status/886144571419246592

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Warfighter Performance Monitoring Continuum

Physical Performance Monitoring Needed

- **Performance readiness**
- **Hazard exposure**
- **Environmental extremes**
- **Injury onset prediction**
- **Physical recovery**
- **Nutritional gaps**

Basic Training

Military Occupational Specialty Training

*Special Operations Training*

Operational Deployment

Behavioral and Psychological Monitoring Needed

- **Cognitive readiness**
- **Skill acquisition**
- **Decision making**
- **Team synergy**
- **Crisis monitoring**
- **Coping adaptions**

Warfighter performance monitoring requires comprehensive information collected from extraordinarily complex environments

Military Wearables Integration Needs
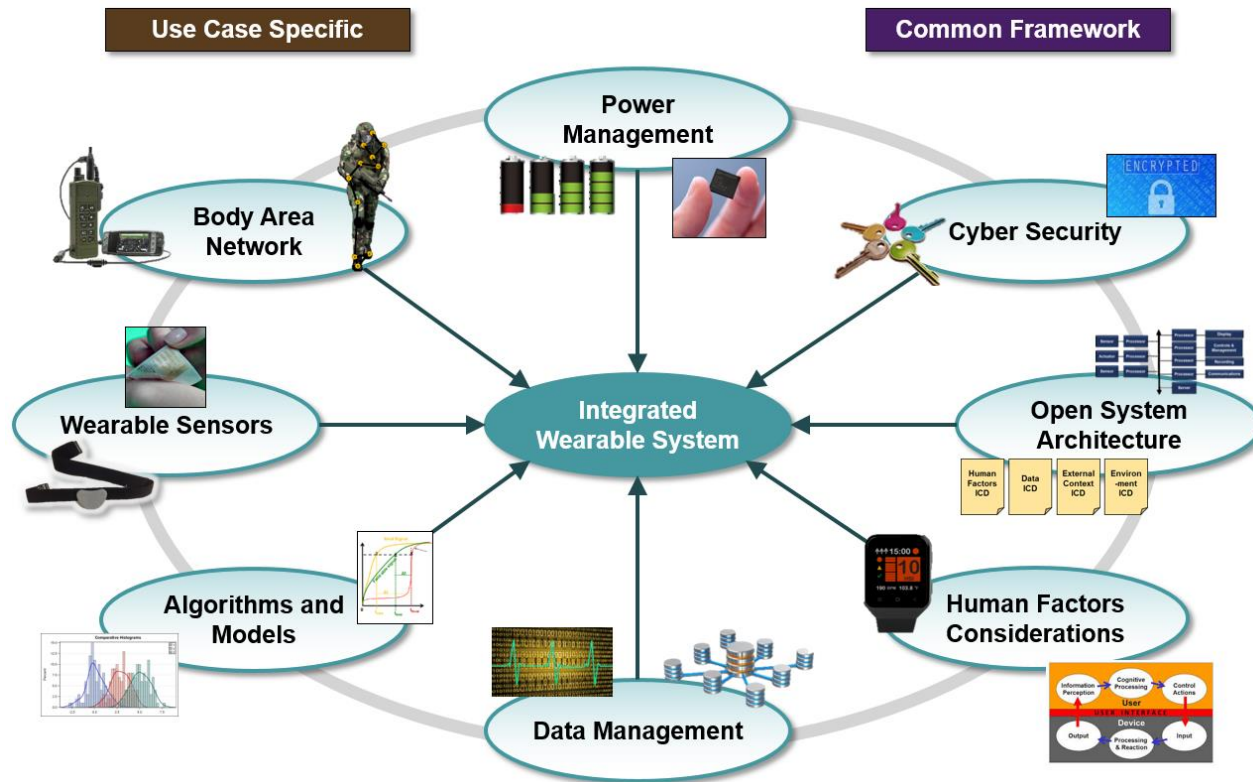
- **Open system architecture that spans stakeholder needs and domain applications**

  - *What are we building toward?*

- **Adaptive design that evolves as prototypes and system functionality are added**

  - *How does emerging technology fit into system architecture?*

- **Systems analysis capability to assess technologies against military end user needs**

  - *What wearables systems are required for specific use cases?*

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Overview of Wearables MBSE-System Architecture

Acquisition / R&D Lead
Strategic priorities

Identifies

Military Mission Planner
Objectives, Context, Constraints

Describes

Use Case
Functional, Structural, Actor Requirements

Decomposition into functional, structural, and actor requirements

Algorithm Developer
Functional capabilities, requirements

Describes

Functional Library
Algorithm descriptions:
Capabilities, requirements

Validation Tools
Compare design to requirements

Structural Library
Design / device descriptions:
design capabilities, structural, performance characteristics

Describes

System Developer
System implementation

MBSE-SA

Provides

- **Multiple views of system requirements**
- **Systems that meet use case requirements**
- **Gaps in current capabilities**

To Inputs   *To Inputs*

MBSE-SA integrates evolving cross-domain knowledge and user inputs into model abstractions, enabling a bridge between wearables systems and end user needs

MBSE-SA: Model Based System Engineering System Architecture

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Outline

- **Program goals**

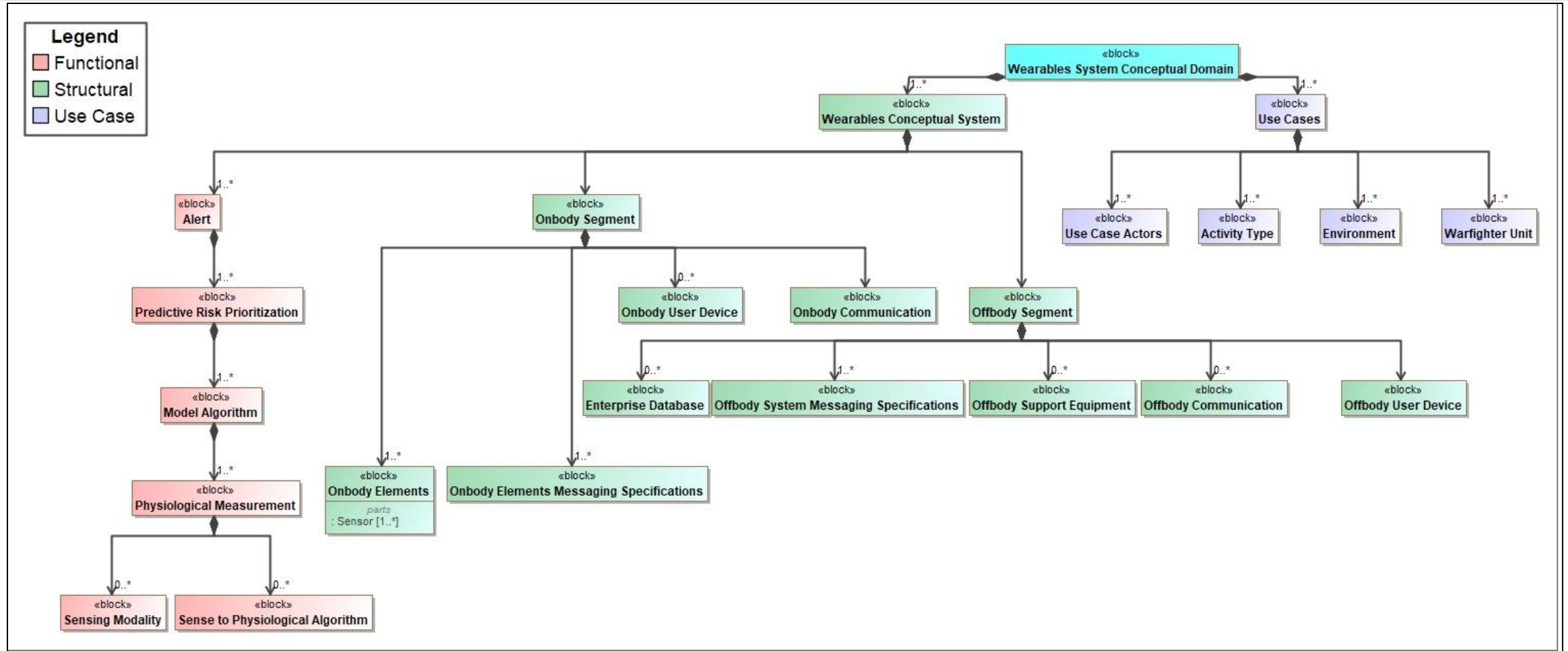- **MBSE system architecture**

- **Future work opportunities**

Overview of Wearables MBSE-SA Methodology

1. Define the conceptual systems architecture framework

2. Build a performance monitoring wearable systems library and a military-specific use-case library

3. Develop a relationship model to encode the relationships among mission characteristics (e.g., physical activity level and environmental conditions), associated physiological states and alerts of interest (e.g., heat stress or cognitive readiness), and specific design implementations

4. Query the relationship model

MBSE-SA: Model Based System Engineering System Architecture

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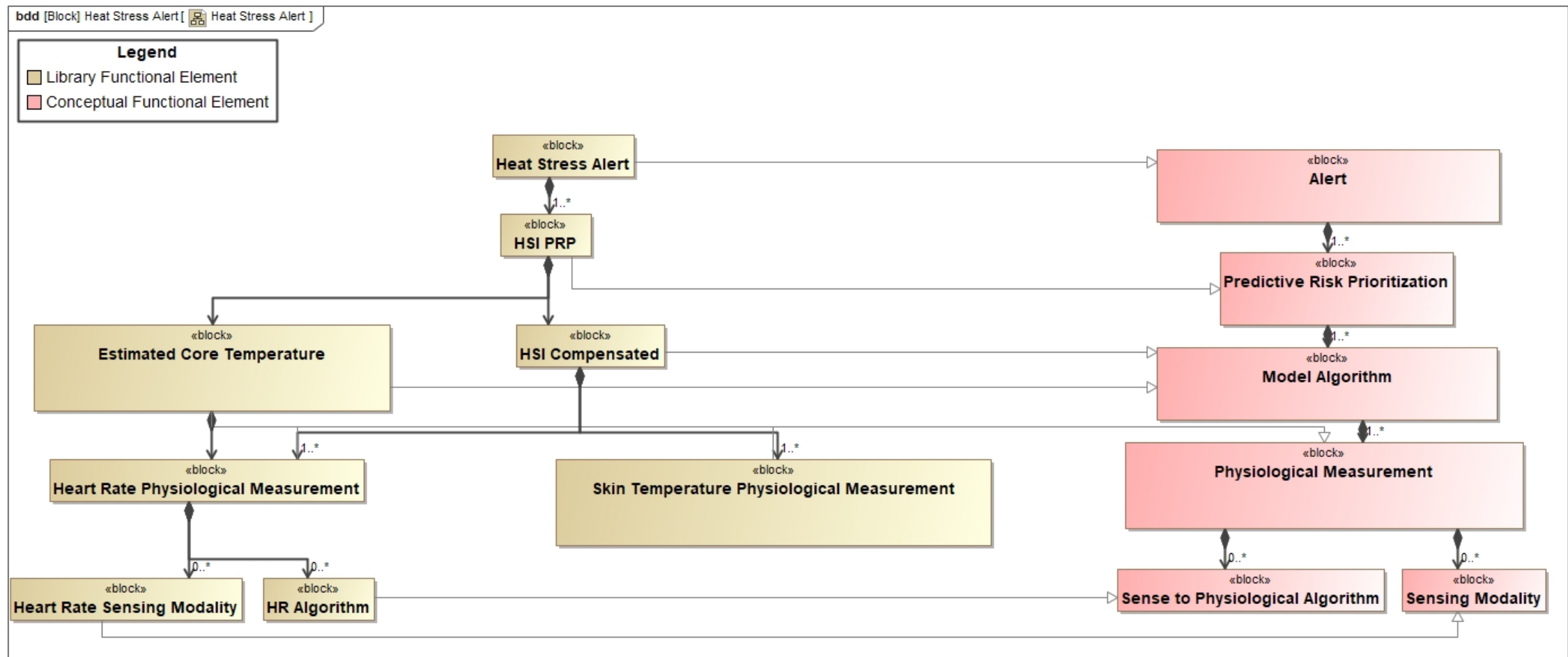# 1. Conceptual Systems Architecture Framework

Conceptual framework enables straightforward integration of new capabilities into the model libraries and supports automatic propagation of characteristics and requirements from one branch to the others

bdd [Block] Heat Stress Alert [Heat Stress Alert]

Legend
- Library Functional Element
- Conceptual Functional Element

«block» Heat Stress Alert

«block» HSI PRP

«block» Estimated Core Temperature

«block» HSI Compensated

«block» Heart Rate Physiological Measurement

«block» Skin Temperature Physiological Measurement

«block» Heart Rate Sensing Modality

«block» HR Algorithm

«block» Alert

«block» Predictive Risk Prioritization

«block» Model Algorithm

«block» Physiological Measurement

«block» Sense to Physiological Algorithm
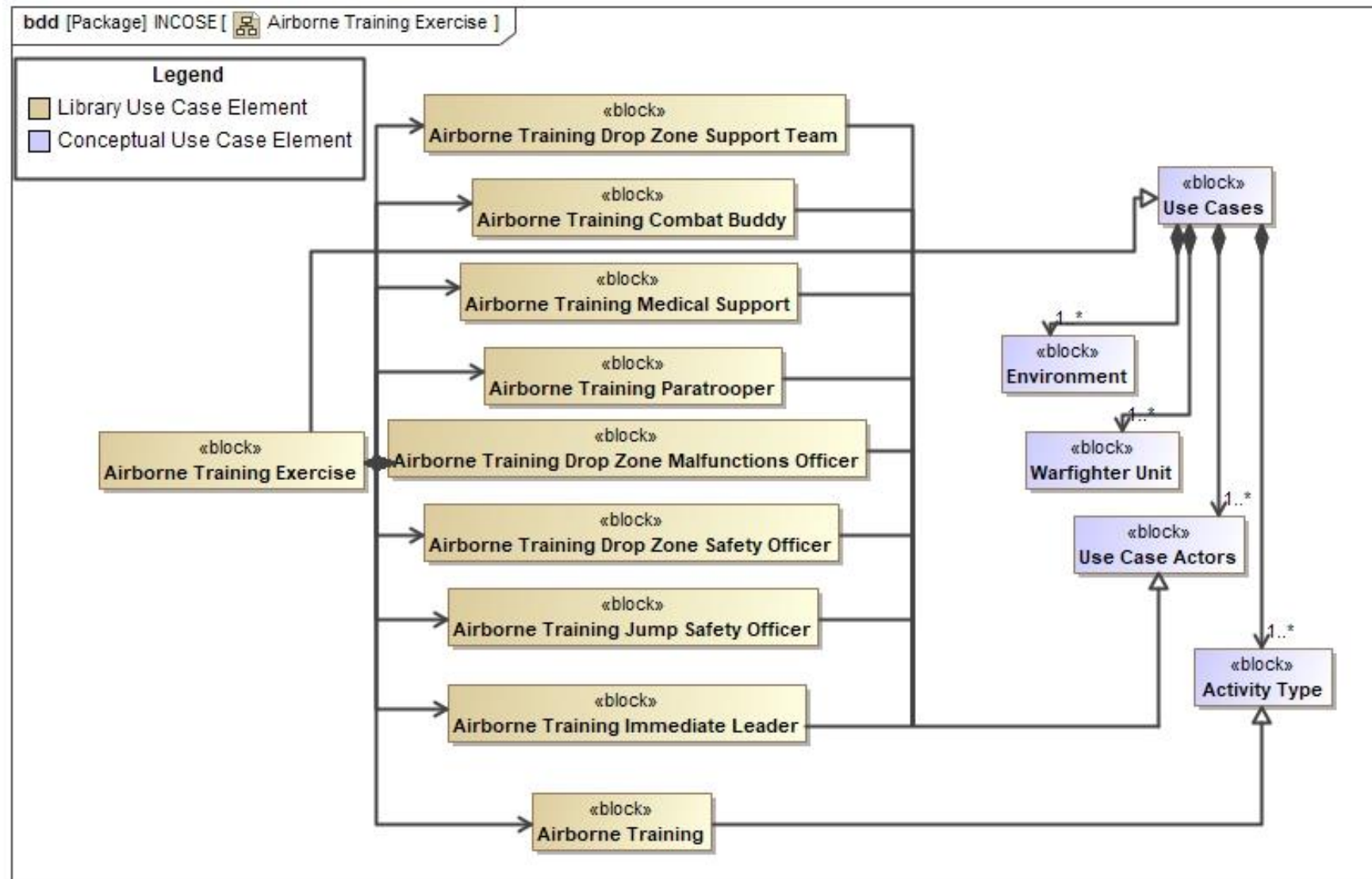
«block» Sensing Modality

Model libraries serve as a database built upon the conceptual framework abstractions, allowing for a common foundation to assess the compatibility and capabilities of real-world systems

HSI: Heat Strain Index
PRP: Predictive Risk Prioritization

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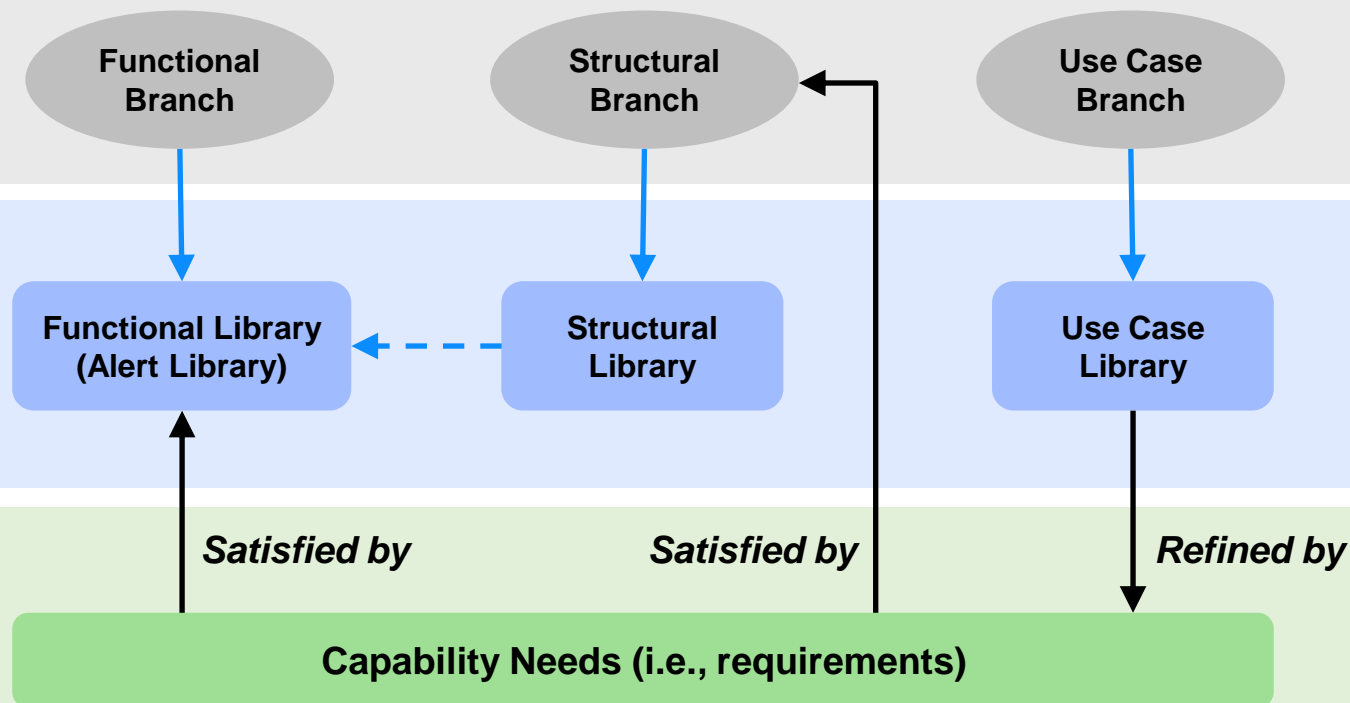MASSACHUSETTS INSTITUTE OF TECHNOLOGY

3. Relationship Model

1) **Wearables Conceptual Framework –** provides consistent database structure for libraries to be built upon

2) **Model Libraries –** enable analysis by creating relationships between conceptual and actual systems

3) **Capability Needs –** refine elements in the use case library and are satisfied by the alert library and conceptual structural branches establishing indirect linkages across the branches

Functional Branch

Structural Branch

Use Case Branch

Functional Library (Alert Library)

Structural Library

Use Case Library

Satisfied by

Satisfied by

Refined by

Capability Needs (i.e., requirements)

- - → **Association relationship**
— → **Generalization relationship**

Relationship model maps the capability needs from end users to the conceptual framework and libraries, enabling the ability to analyze multiple system options against mission use cases

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3. Relationship Model
Example: Capability Needs Table for Airborne Training

Criteria

Element Type: `Requirement`   `...`   Scope (optional): `Use Case Mappings {}xy`   `...`   Filter: ▽▾

| #	Name	Satisfied By	Refines
10	[R] Heat Alert for Airborne Phase I exercise	▭ Heat Stress Alert	▭ Airborne Training Jump Safety Officer ▭ Airborne Training Immediate Leader ▭ Airborne Training Medical Support
11	[R] Hydration Alert for Airborne Phase I exercise	▭ Hydration Alert	▭ Airborne Training Jump Safety Officer ▭ Airborne Training Medical Support ▭ Airborne Training Immediate Leader ▭ Airborne Training Combat Buddy
12	[R] Nutritional Status for Airborne Phase I exercise	▭ Metabolic State Alert	▭ Airborne Training Medical Support ▭ Airborne Training Immediate Leader
13	[R] Cognitive Alert for Airborne Phase I exercise	▭ Cognitive Readiness Alert	▭ Airborne Training Medical Support ▭ Airborne Training Immediate Leader ▭ Airborne Training Combat Buddy ▭ Airborne Training Jump Safety Officer
14	[R] MSI Alert for Airborne Phase I exercise	▭ Musculoskeletal Injury Alert	▭ Airborne Training Medical Support ▭ Airborne Training Jump Safety Officer
15	[R] Heart Rate Monitoring for Airborne Phase II/II Excerise	▭ Heart Rate Physiological Measurement	▭ Airborne Training Medical Support
16	[R] Movement Alert for Airborne Phase II/III training	▭ Movement Alert	▭ Airborne Training Medical Support ▭ Airborne Training Drop Zone Support Team ▭ Airborne Training Immediate Leader

Military Mission Planner Inputs

- **Mission Objectives, Context, Constraints**
  - Activity Type: Airborne Training
  - Actors: Airborne Drop Zone Officer, Airborne Drop Zone Safety, etc.
  - Environment: Night, Overcast, Low Illumination, 90% Humidity, etc.
  - Warfighter: Body Armor, Experience Level, Load, etc.

System and Algorithm Developer Inputs

- **Wearables System Functional Elements**
  - Alerts: Heat Stress, Cold Stress, Cognitive, etc.

- **Wearables System Structural Elements**
  - Onbody Elements: Communications, Messaging Spec, Devices, etc.
  - Offbody Elements: Communications, Messaging Spec, Devices, etc.

Output from the Model: Systems Capabilities against Use Case Needs

Legend
- 🟩 What System Has
- 🟧 What Use Case Needs
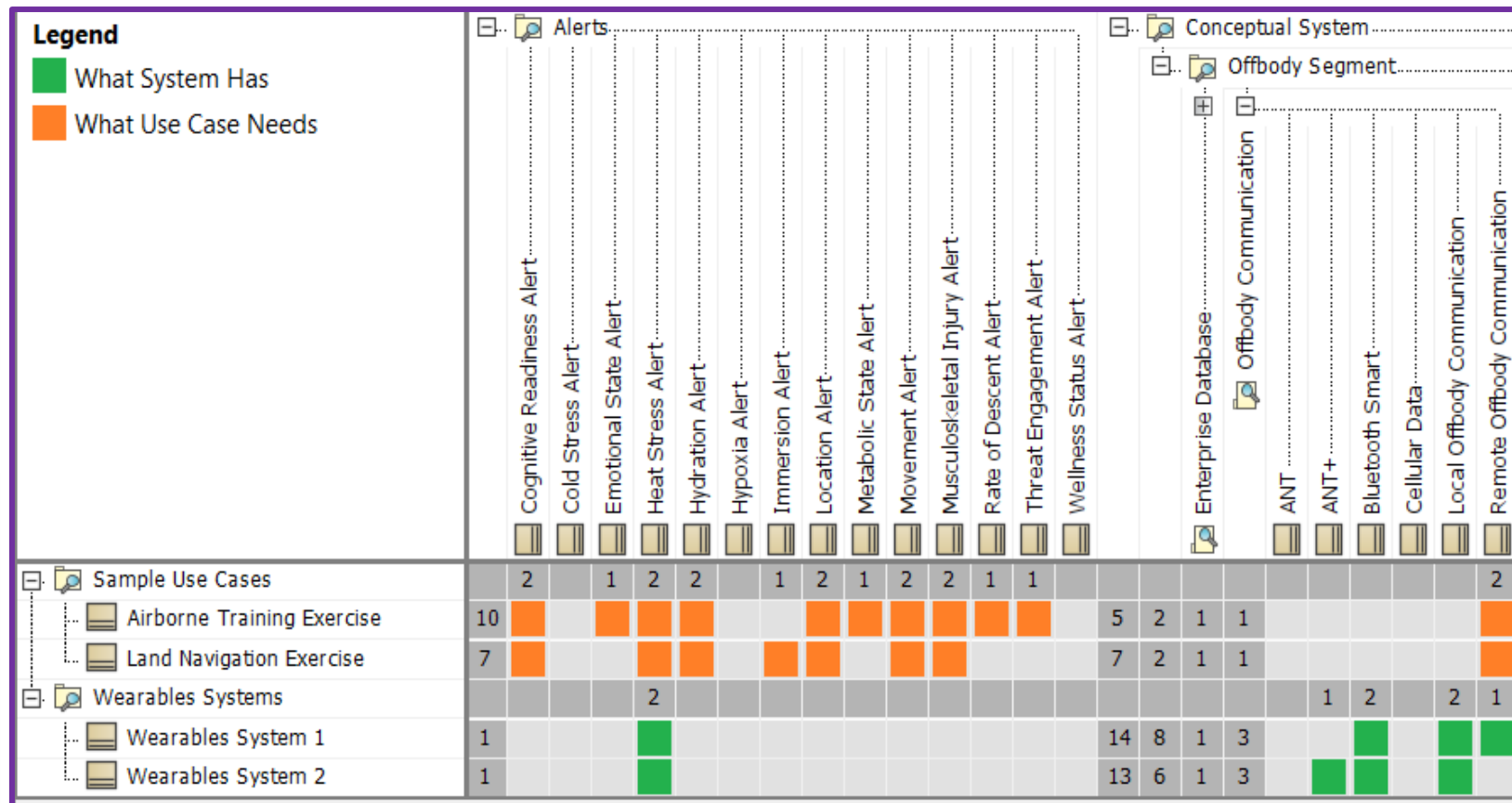
Identifies capability gaps and potential opportunities for wider application of wearable technologies that align with mission priorities
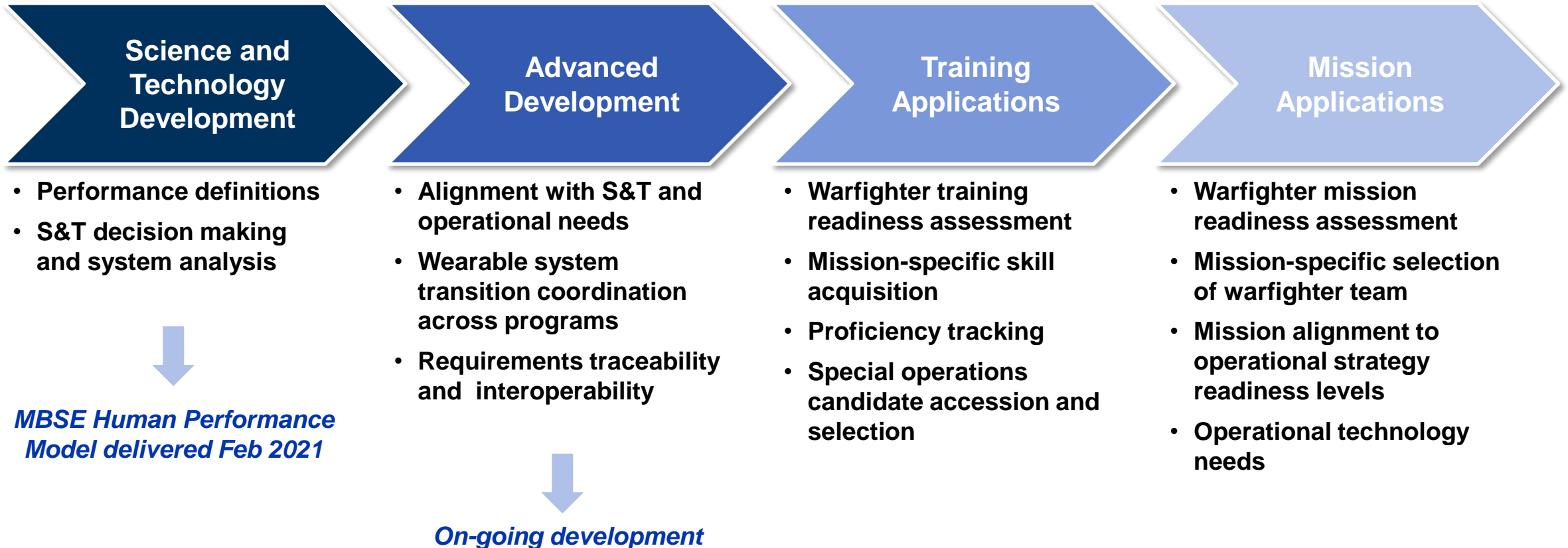
Outline

- **Program goals**

- **MBSE system architecture**

➡️ - **Future work opportunities**

Human Health and Performance Systems MBSE-SA Framework Interfaces

Science and Technology Development

- **Performance definitions**
- **S&T decision making and system analysis**

MBSE Human Performance Model delivered Feb 2021

Advanced Development

- **Alignment with S&T and operational needs**
- **Wearable system transition coordination across programs**
- **Requirements traceability and interoperability**

On-going development

Training Applications

- **Warfighter training readiness assessment**
- **Mission-specific skill acquisition**
- **Proficiency tracking**
- **Special operations candidate accession and selection**

Mission Applications

- **Warfighter mission readiness assessment**
- **Mission-specific selection of warfighter team**
- **Mission alignment to operational strategy readiness levels**
- **Operational technology needs**

- **Wearable MBSE-SA is a foundational tool on which stakeholder applications can be built**
- **MBSE-SA facilitates integration across DoD programs that require performance monitoring applications**

MBSE-SA: Model Based System Engineering – System Architecture

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Ongoing and Future Work Opportunities

- **Expand MBSE models for transition to broader usage**

    - **Improve tool usability for easier ingestion of stakeholder information**

    - **Expand access across stakeholder and technology development communities**

    - **Define access management, configuration management, scope, IP protection, and data security**

- **Populate model libraries with routine stakeholder input to capture evolving use cases, capability needs, and emerging technologies**

- **Develop and extend framework applications to meet the needs of the S&T, advanced development, training, and operational communities**

S&T: Science & Technology
IP: Intellectual Property

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