Always a Step Ahead
ARDEC
ARMAMENTS

Enhancing Future Soldier Systems through the Use of the Systems Modeling Language to Incorporate Human Aspects into the Soldier as a System Definition

Presenter: Sean F. Pham
Shauna M. Dorsey, Frank B. Torres, Dana E. Perriello

NDIA Systems Engineering Conference, 25 October 2017

UNPARALLELED
COMMITMENT
& SOLUTIONS

Act like someone's life depends on what we do.

U.S. ARMY
U.S. ARMY RDECOM®
U.S. ARMY ARMAMENT
RESEARCH, DEVELOPMENT
& ENGINEERING CENTER
US ARMY NATICK SOLDIER RD&E CENTER

SOLDIER AS A SYSTEM

Problem: The U.S. Army has historically focused on the development and optimization of Soldier **equipment**, leading to integration challenges between Soldiers and their equipment.

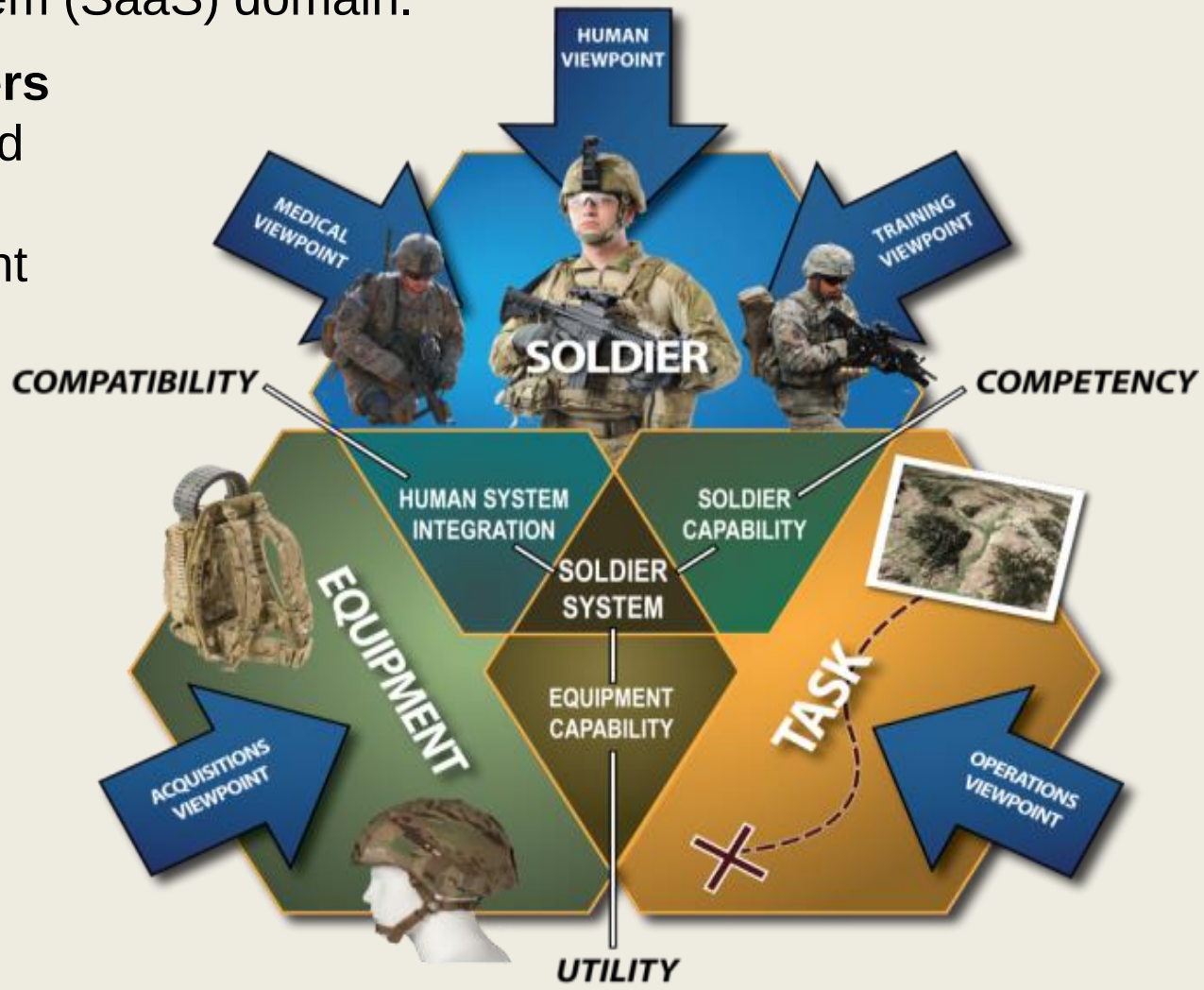
Best:
- Unmanned aerial vehicles
- Operational rations
- Organization/leadership
- Quality of life standards, etc.

It's not just about Soldier equipment. We must also understand and predict the performance of the ***full system***, inclusive of the Soldier, his/her equipment, and the tasks he/she must perform.

SOLDIER SYSTEM ENGINEERING ARCHITECTURE

Objectives: Create a principle-based Soldier architecture and framework to enable a **system level tradeoff analysis** of the Soldier as a System (SaaS) domain.

- Create the **foundation for design parameters** for the next generation of Soldier systems and subsystems, which considers the complete **Soldier as a System** with the full complement of equipment, the human performance capabilities, and the mission tasks.

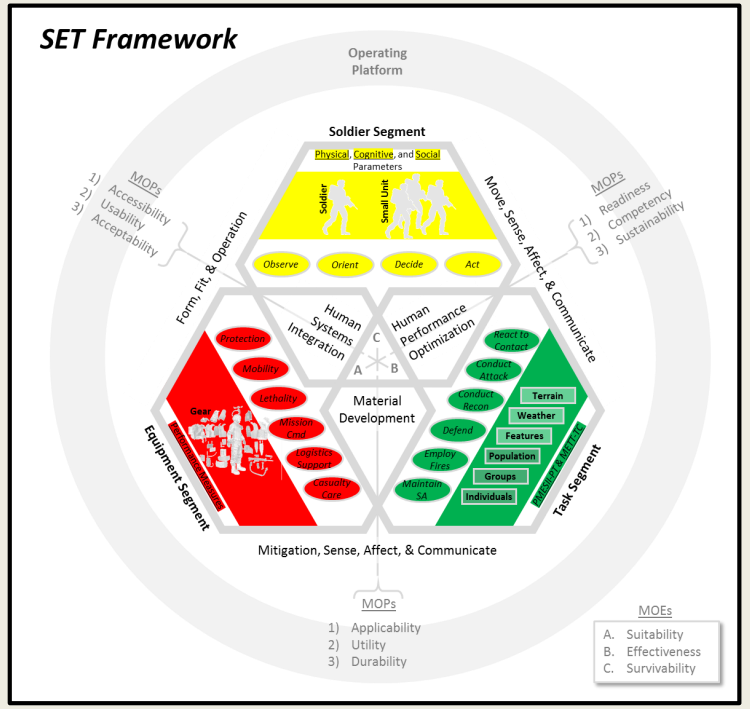


Anticipated Outcomes:

- Increased efficiencies and optimized performance of the Soldier as a System.
- Enterprise approach across Soldier-Small Unit Science and Technology (S&T) efforts, combat developers, and acquisition communities.

SOLDIER SYSTEM ENGINEERING ARCHITECTURE

Purpose: Utilize Systems Engineering tools and processes to allow stakeholders across the Soldier Enterprise to manage the overwhelming complexity of the Soldier as a System domain.

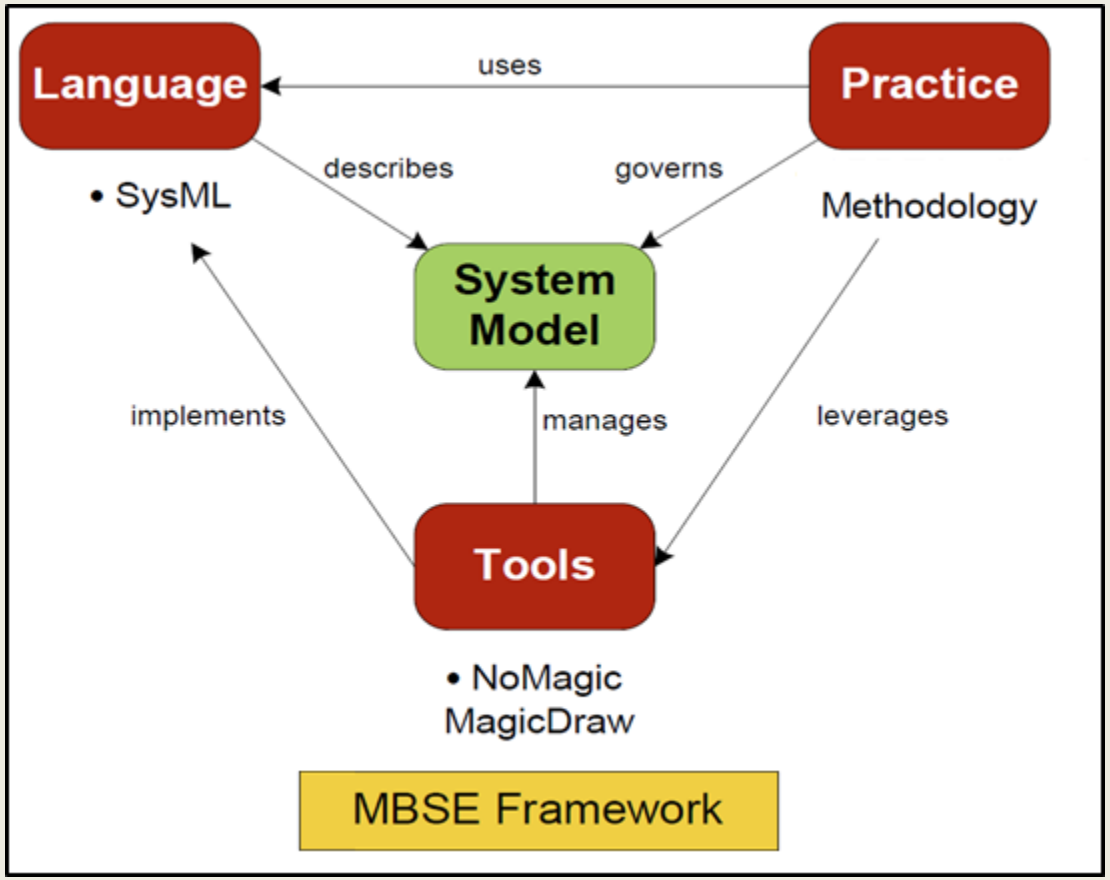


Soldier System Engineering Architecture (SSEA) is integrating these tools and processes for the Soldier Enterprise.

MODEL BASED SE TO DEFINE SAAS DOMAIN

Model Based Systems Engineering (MBSE): A Systems Engineering practice that uses **models** as the primary means of information exchange between engineers, rather than document-based.

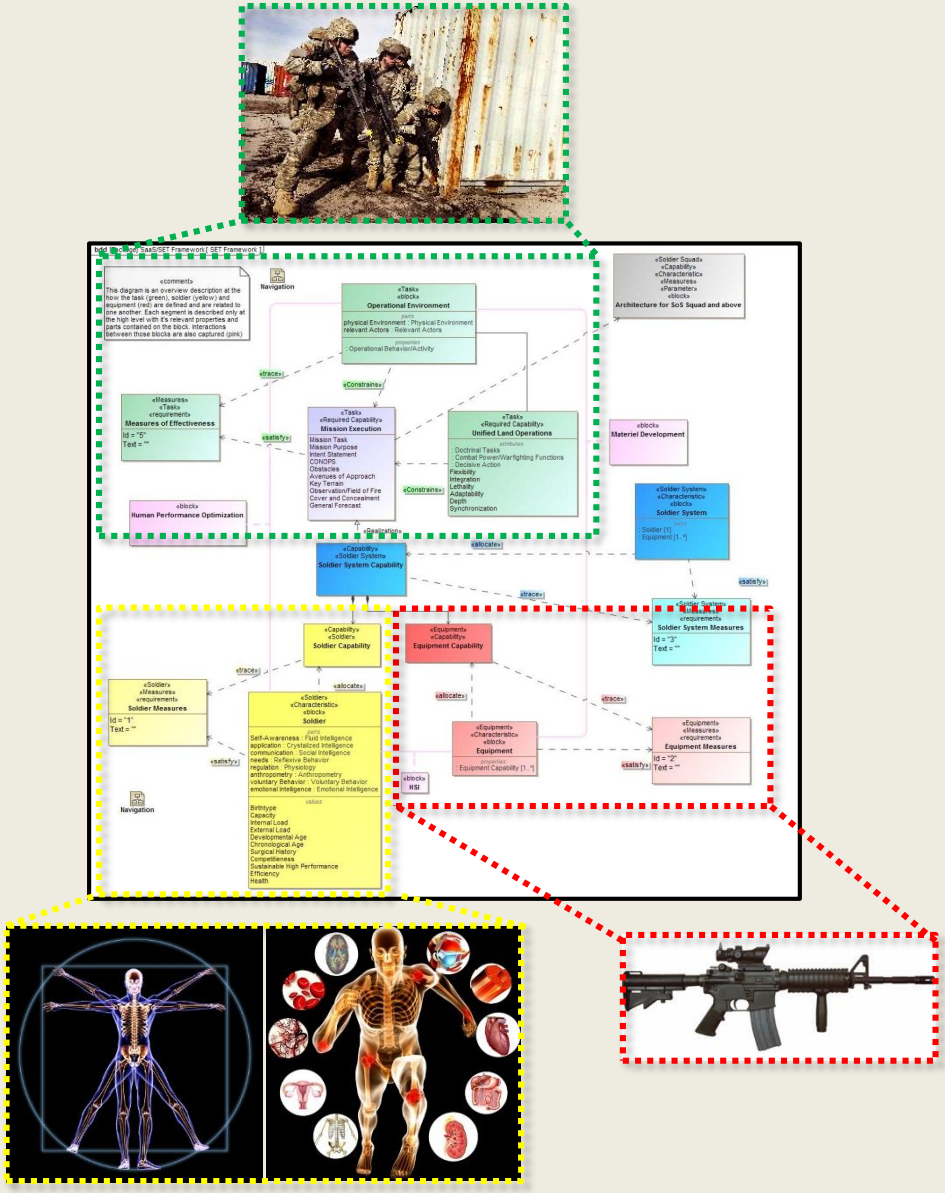
- MBSE allows for:
  - Graphically rich architectural product development of complex systems.
  - Relationship visualizations.
  - Interactive traceability handling.
  - Commonality of data and information throughout the project and across related projects.
  - Movement from document centric to model centric.



MBSE provides graphical views of SE products to inform SSEA trade analysis.

SOLDIER AS A SYSTEM MODELS

- The **System Model**:
  - **Characterizes** the Soldier as a System (SaaS) **domain** in terms of the human dimension, materiel solutions, and operational environment (i.e., the Soldier, Equipment, Task [SET] framework).
  - Formalizes the **definition** of the **SaaS** domain.
    → Elements of the Soldier, Equipment, and Task, along with their interactions and interrelationships.
- **System Modeling Language (SysML)**:
  - **Captures the system model** and **defines the boundaries** of the system space.
    → Enables decomposition of the SaaS domain and establishes a common vocabulary.
  - Provides a **common underpinning for SSEA**, allowing **stakeholders** to further **understand** their piece of the SaaS domain and its impact points over the full system space.

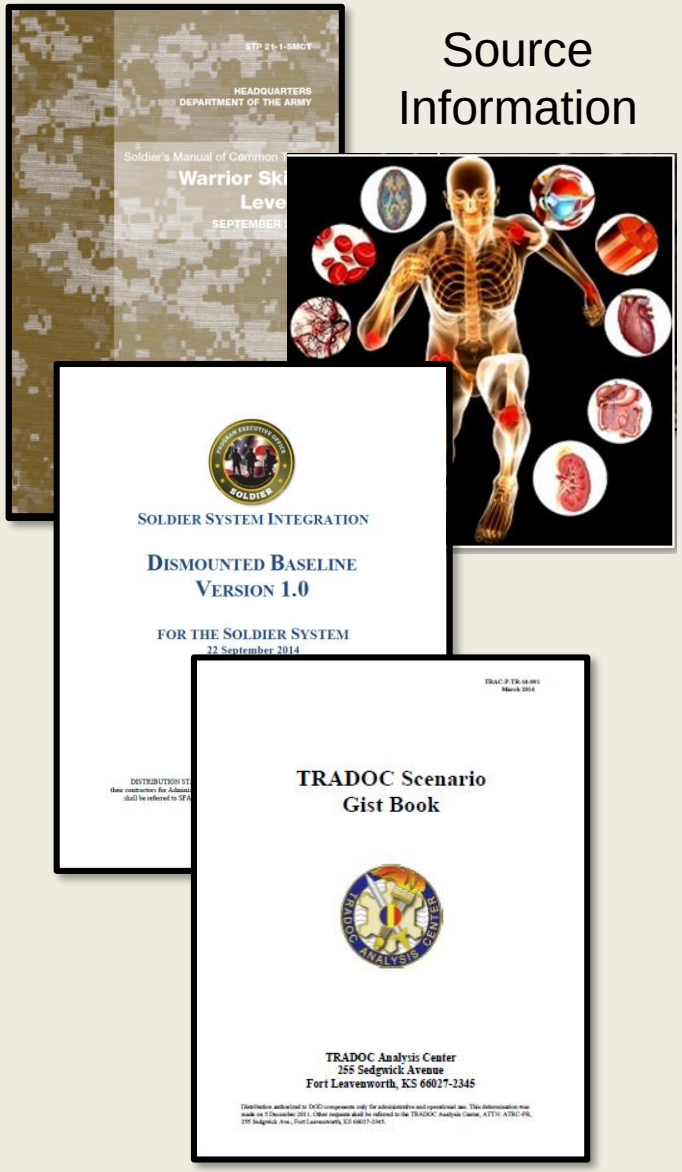


SysML SaaS Model Value Proposition

1. Comprehensive Reference Model
   - Provides a centralized focal point to **understand the elements** and **relationships** within the Soldier as a System (SaaS) domain.
     - Enables SSEA stakeholders/users to know where their products, decisions, and solutions fit in the domain and what they impact or what impacts them.
2. Standardized Soldier as a System Documentation
   - **Common language** to translate between technical, programmatic, and user communities.
     - Supports understanding and communication to facilitate informed decisions.
3. Starter Model for Model Based Systems Engineering (*future*)
   - Reduces rework, acclimates new team members, builds on lessons learned, and supports **sharing of knowledge** across communities.

SOLDIER AS A SYSTEM MODELS

Source Information

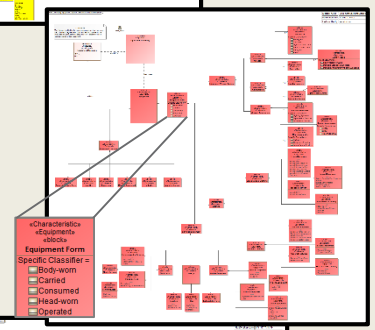


Soldier Model

Defines: *Anthropometric, Physiological, Behavioral, and Intelligence Elements*

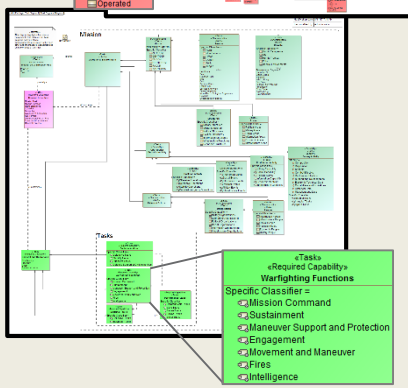
Equipment Model

Defines: *Structural and Behavioral Elements*



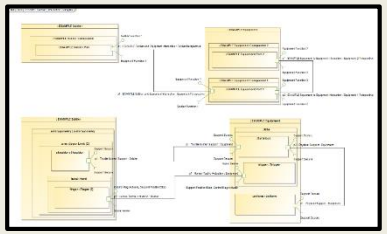
Task Model

Defines: *Physical Environment, Relevant Actors, Operational Behavior, and Unified Land Operations*



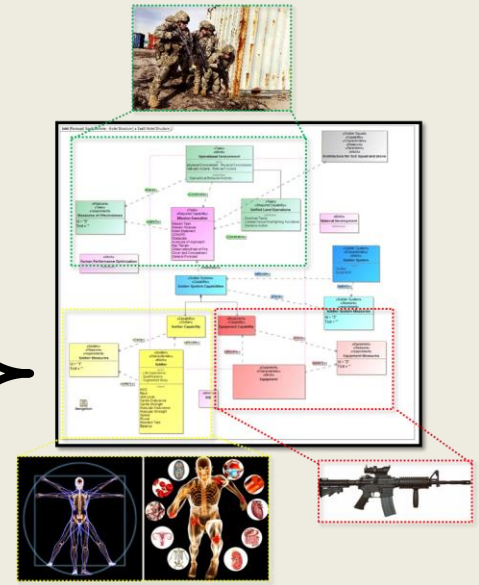
Interaction Model

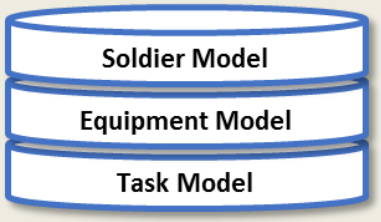
Defines: *Connections, Ports (structural), Interfaces (behavioral), and Flow (parametric)*



Integrate into the SaaS Reference Model

Fully-Integrated Reference Model

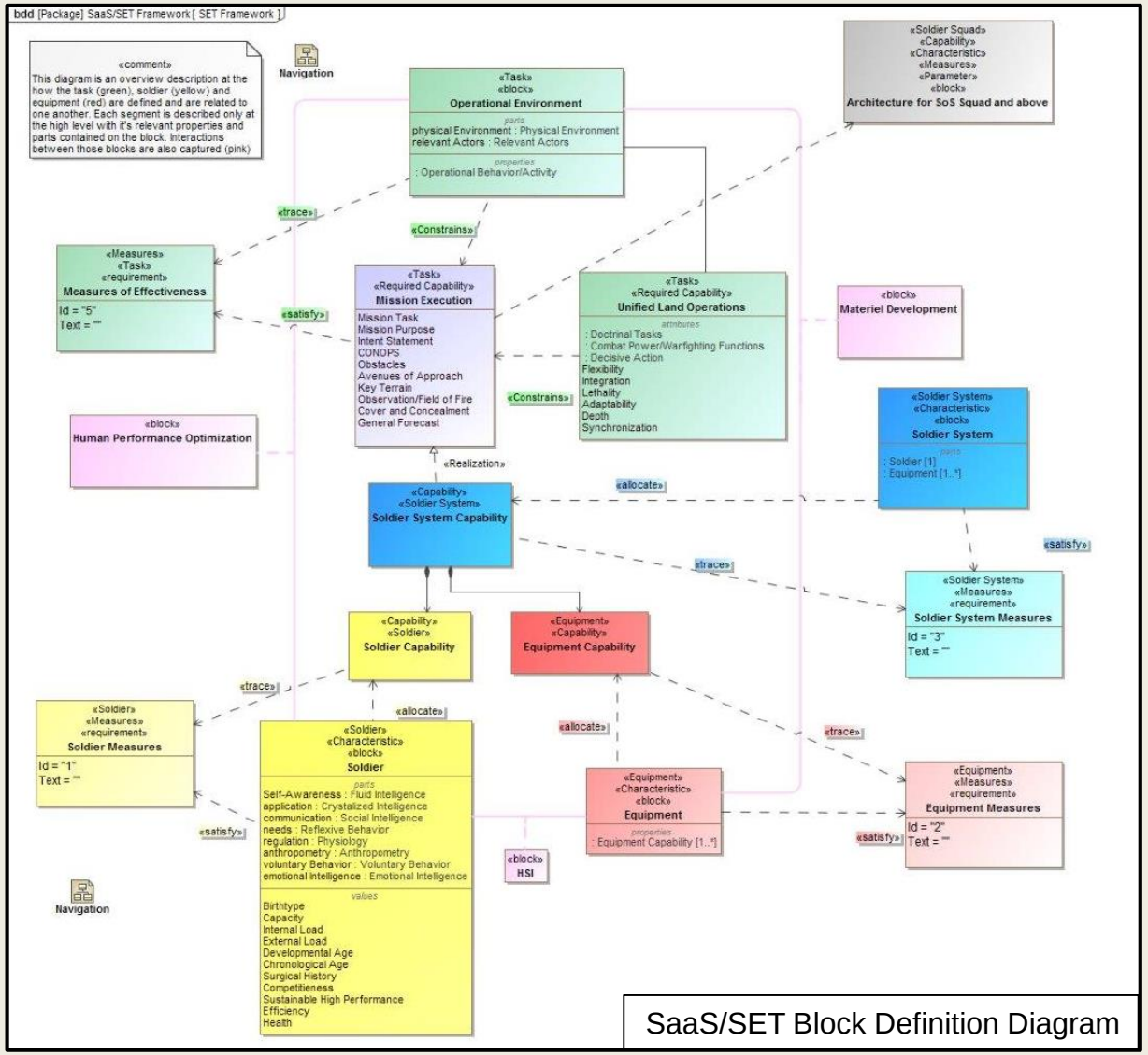




TeamWorks Server

SaaS Model Structure

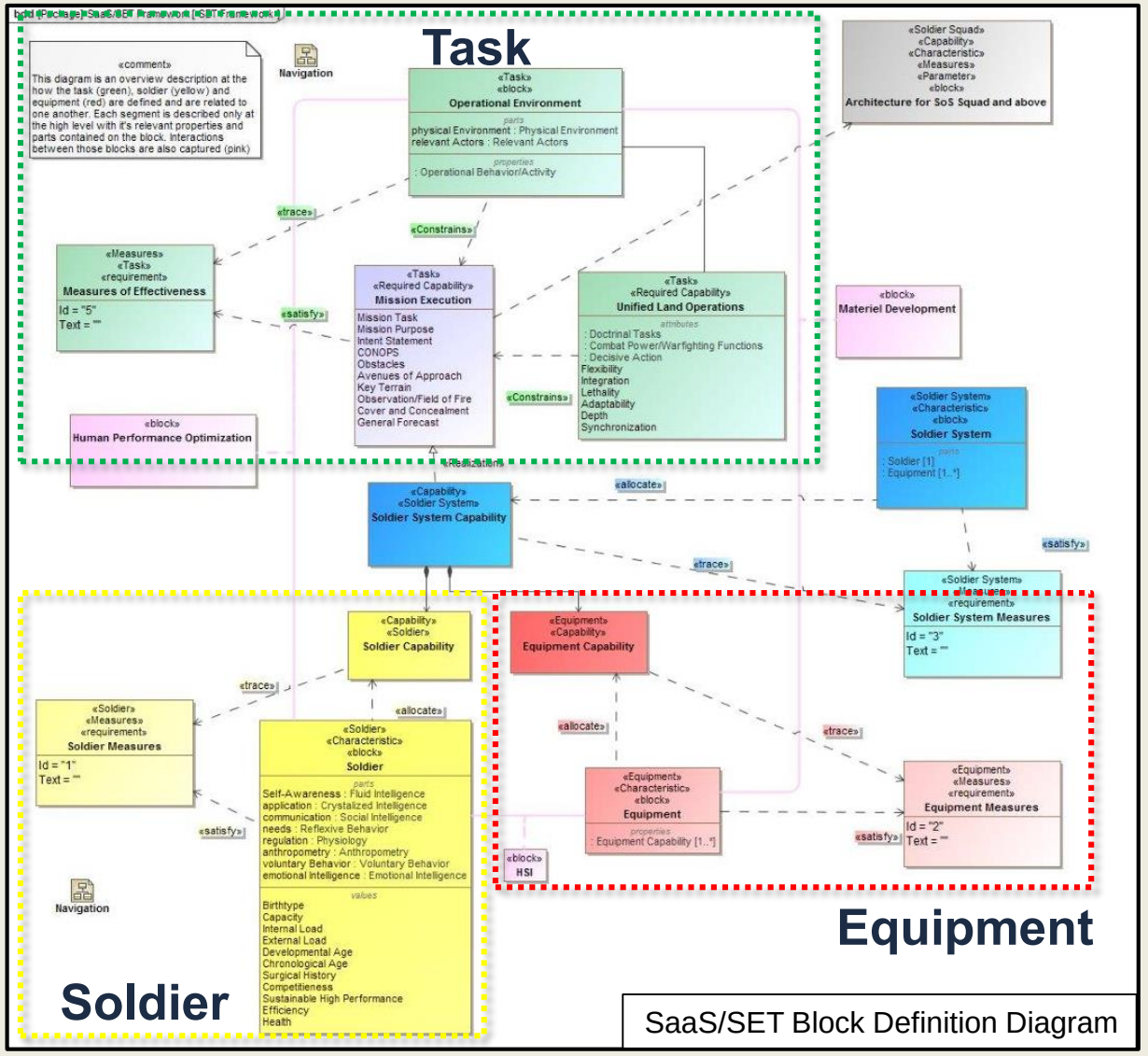
- Purpose of the Model Structure:
  - Define the domain/system space (SaaS) and boundaries.
  - Serve as a central hub for the defined SaaS components and relationships.
    - Comprised of the soldier system within an operational context.
    - Displays any interrelationships between the primary model components.



SaaS/SET Block Definition Diagram

SaaS Model Structure

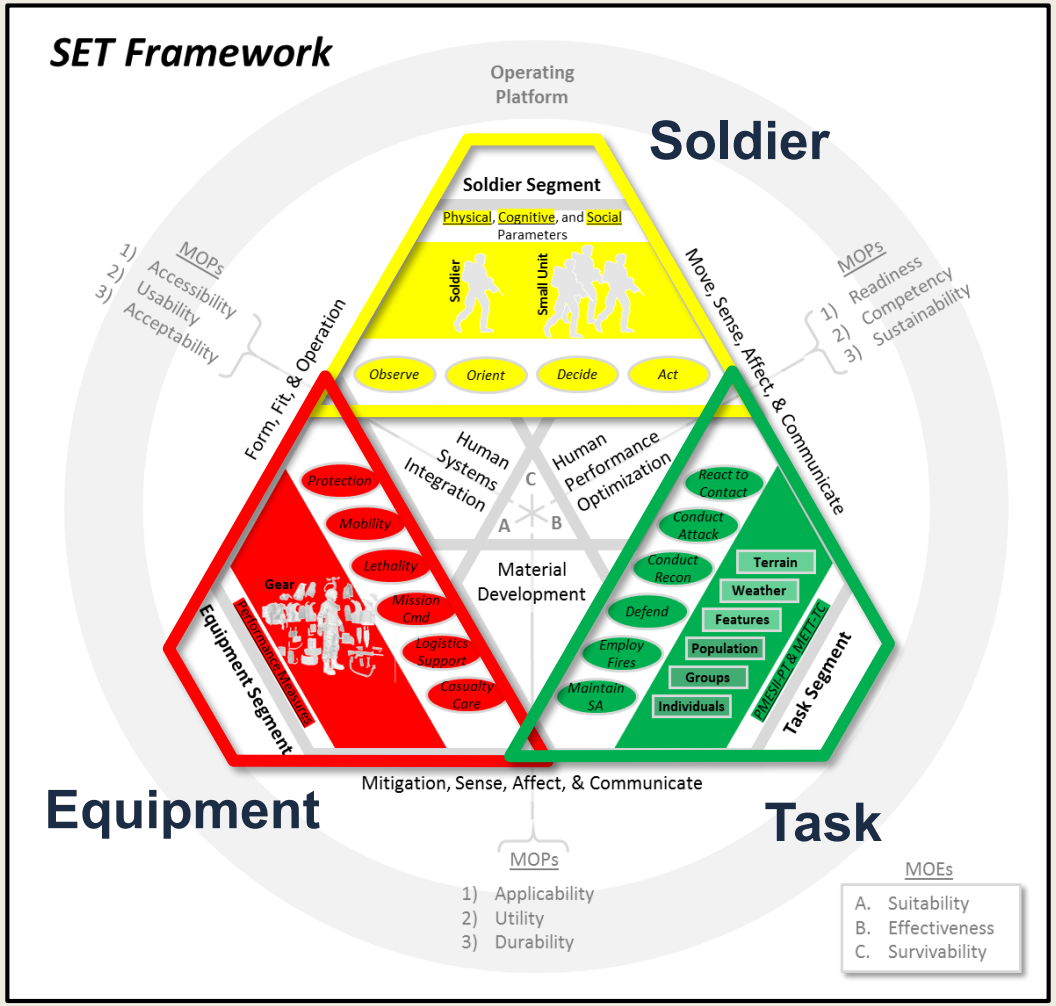
Scenario: Soldier engaging an enemy target.



SaaS/SET Block Definition Diagram

SOLDIER, EQUIPMENT, AND TASK SEGMENTS

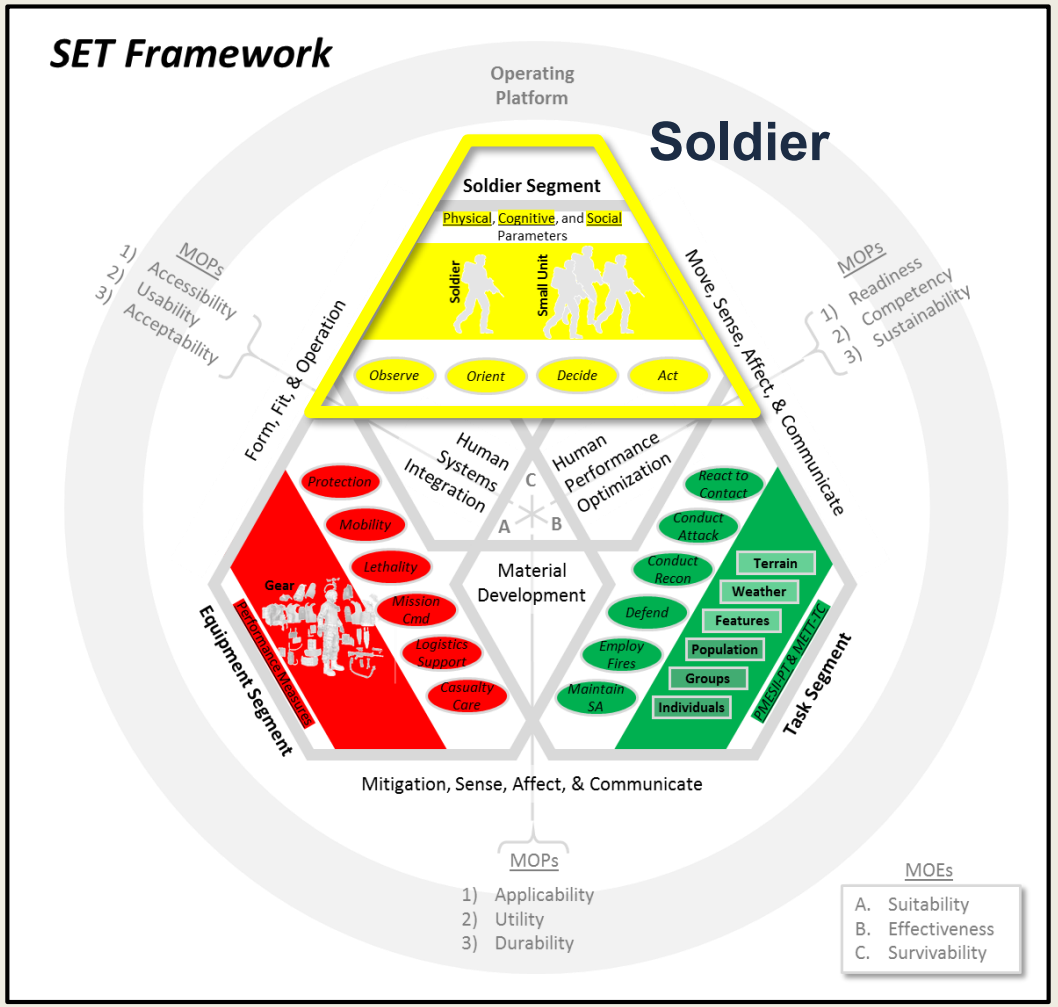
Purpose: Define the elements and relationships contained within Soldier, Equipment, and Task (SET) segments of the Soldier as a System (SaaS) model.



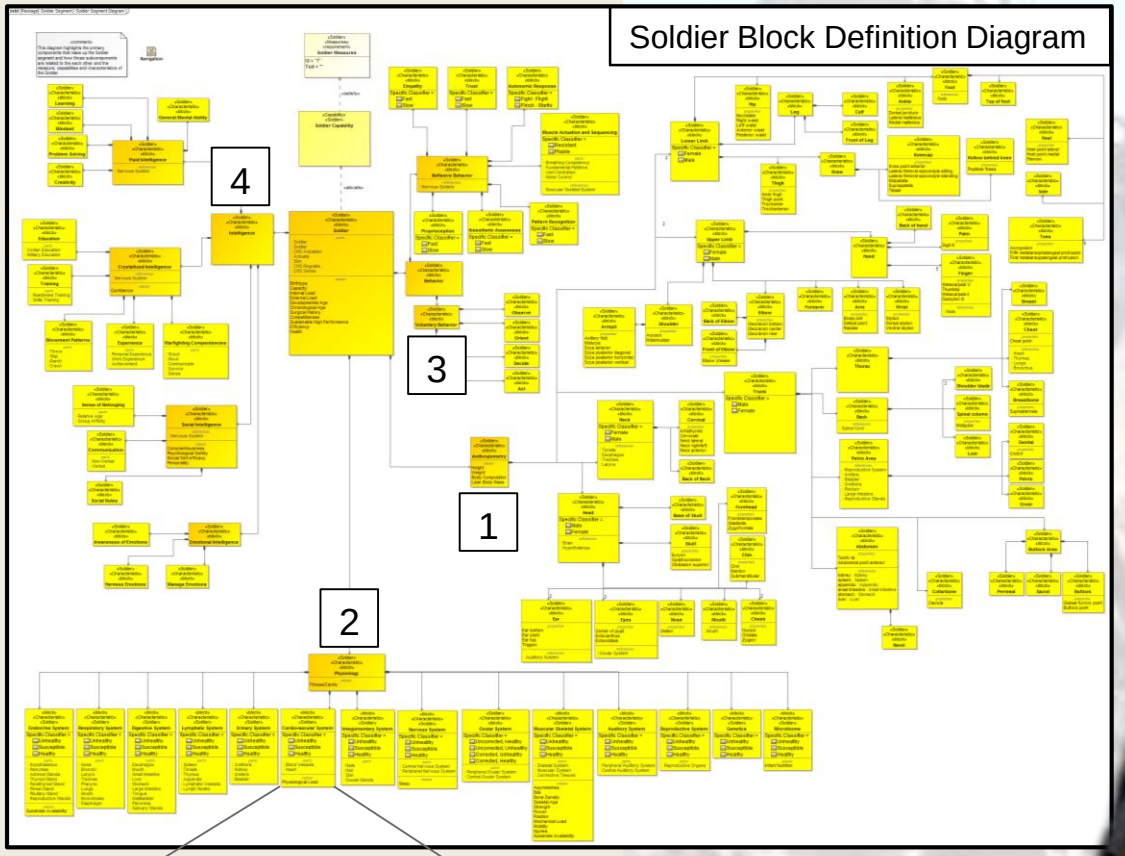
SOLDIER SEGMENT OF THE MODEL

Purpose: Define the elements and relationships within the human dimension, which includes cognitive, physical, emotional, and social parameters to further characterize the Soldier.

UNCLASSIFIED//DISTRIBUTION A



SOLDIER AS A SYSTEM: SOLDIER SEGMENT OF THE MODEL



Four Main Components:

1. *Anthropometry – Physical structures of the human*
2. *Physiology – Internal regulatory systems of the human*
3. *Behavior – Voluntary (i.e., cognitively founded) and reflexive (i.e., "hard-wired") behaviors*
4. *Intelligence – Fluid (i.e., creativity and learning), crystalized (i.e., prior skills and knowledge), social, and emotional intelligence*

Component Classifiers:

- *Size and shape*
- *Health state*
- *Response*
- *Creativity and learning*
- *Education and experiences*
- *Communication style*
- *Emotions*

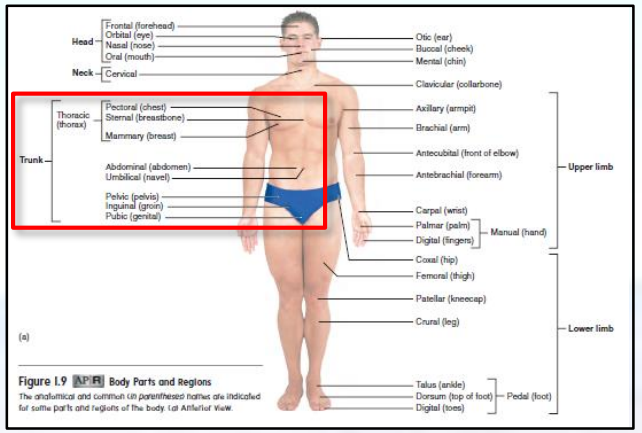
Ports / Interactions (examples):

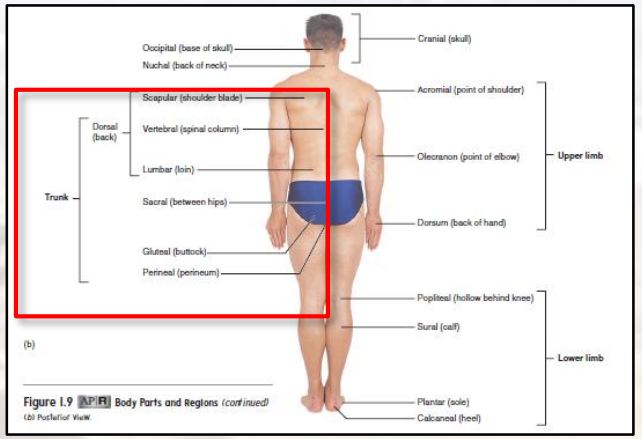
- *Shoulder / Support, Stabilize*
- *Hand / Support, Secure*
- *Finger / Control Magnitude, Actuate*
- *Eye / Signal Sense*
- *Body / Support, Secure, Attach*

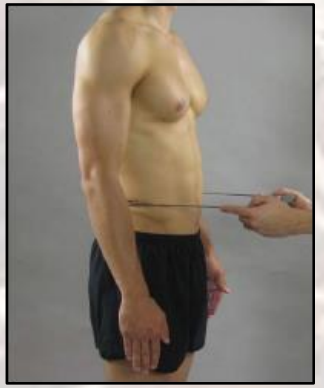
SOLDIER AS A SYSTEM: SOLDIER SEGMENT OF THE MODEL

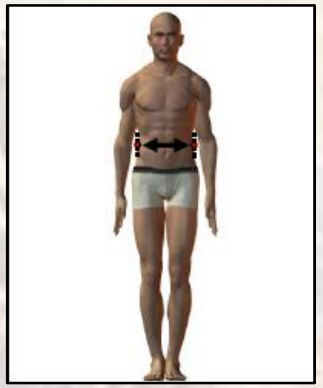
Soldier Block Definition Diagram

Soldier Anthropometrics







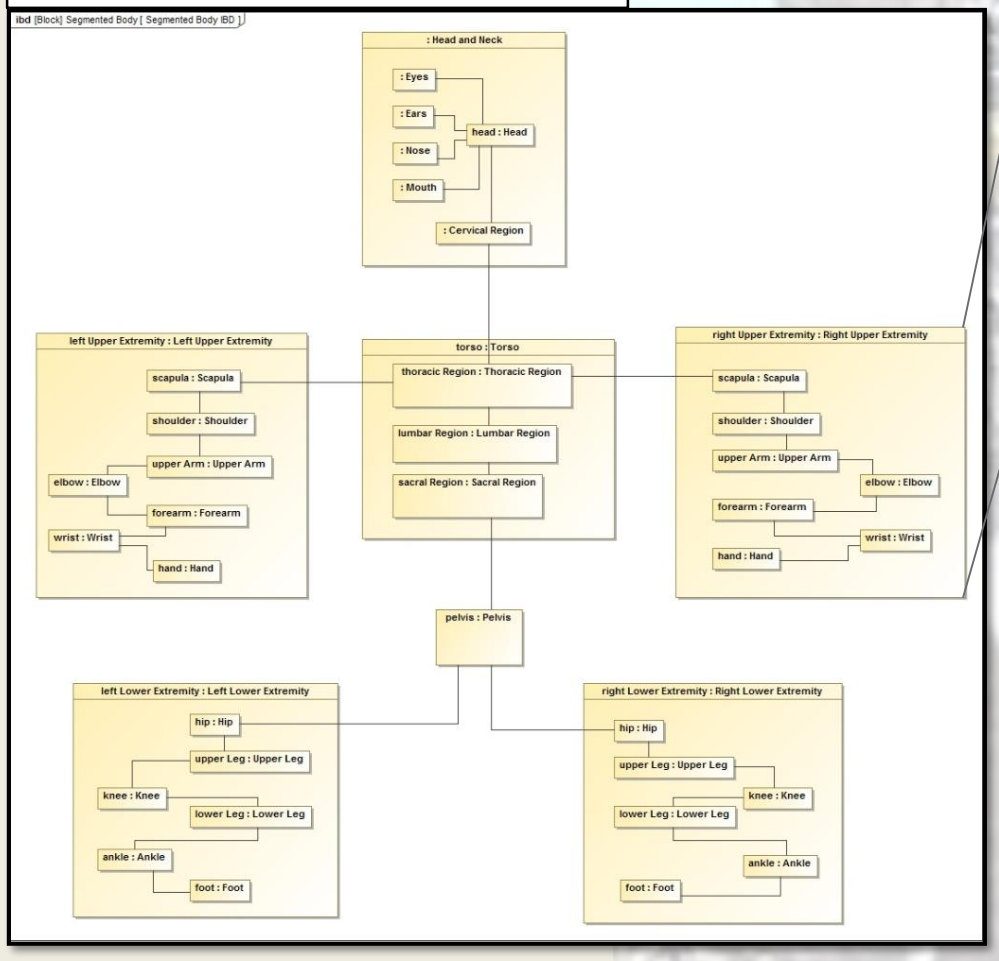


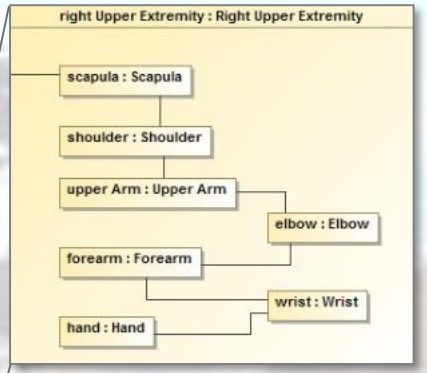
VanPutte CL, et al. Seeley's Essentials of Anatomy and Physiology, 9th Ed. 2014.

Gordon CG, et al. 2012 Anthropometric Survey of U.S. Army Personnel. NSRDEC. 2012.

SOLDIER AS A SYSTEM: SOLDIER SEGMENT OF THE MODEL

Segmented Body Internal Block Diagram



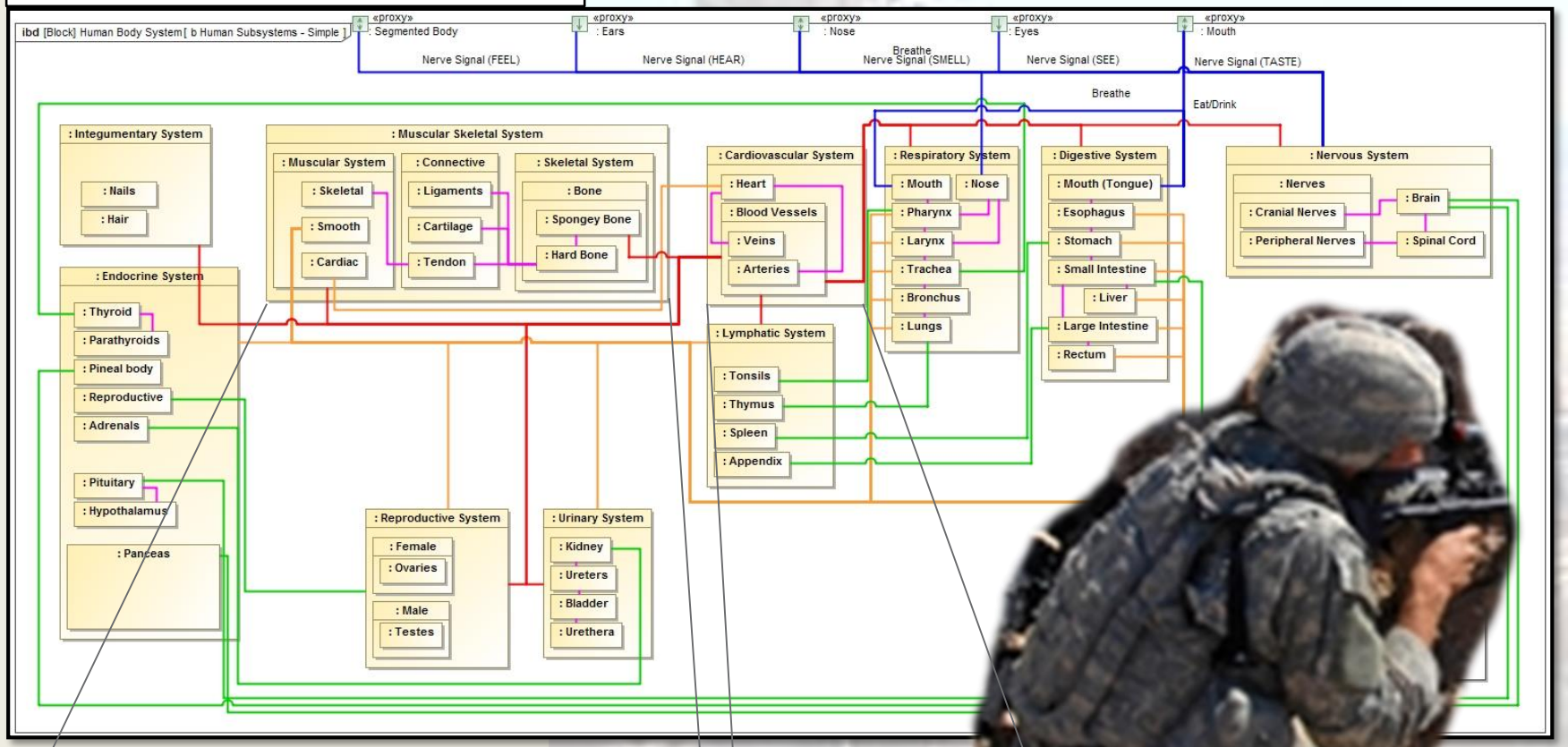


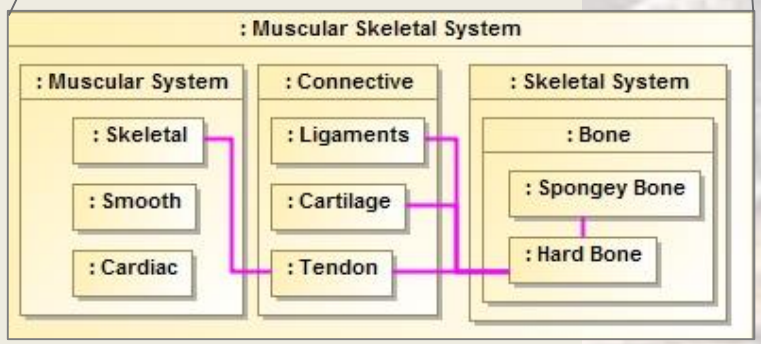
Purpose: Provide a decomposition of the physical anatomical regions of the human body and the connections between those regions of the human body.

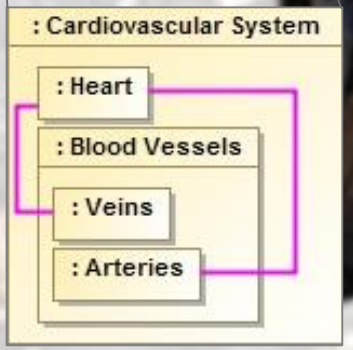
Application (*future*): Show the "connections" between the anatomical body regions and allow for further parameterization and alignment to support future modeling capabilities.

SOLDIER AS A SYSTEM: SOLDIER SEGMENT OF THE MODEL

Human Subsystem Internal Block Diagram





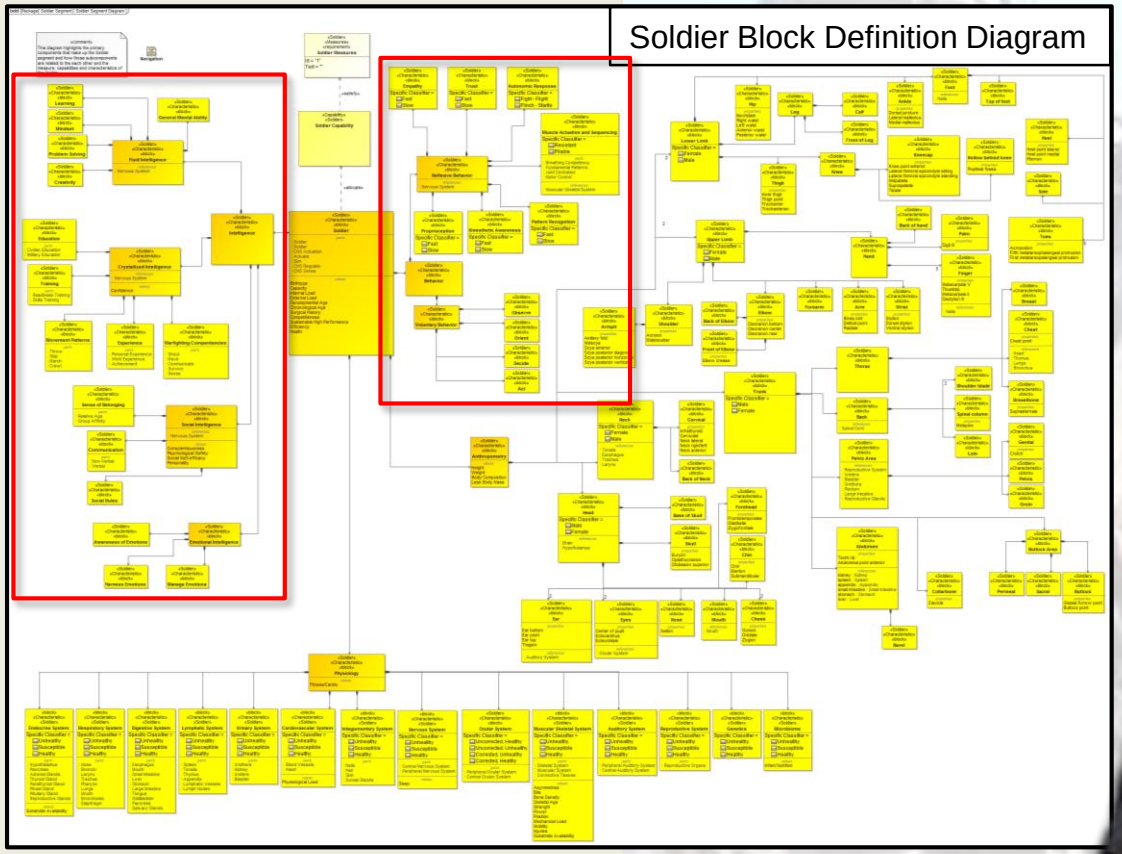


Purpose: Provide a breakdown of the internal regulatory subsystems within the human body and the corresponding anatomical connections between the systems.

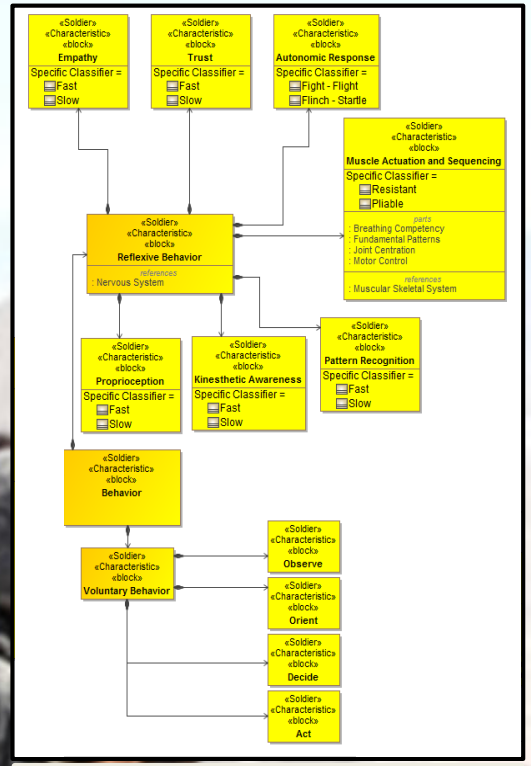
Application (*future*): Model the connections between the outside world and the internal regulatory systems of the human body.

SOLDIER AS A SYSTEM: SOLDIER SEGMENT OF THE MODEL

Soldier Block Definition Diagram



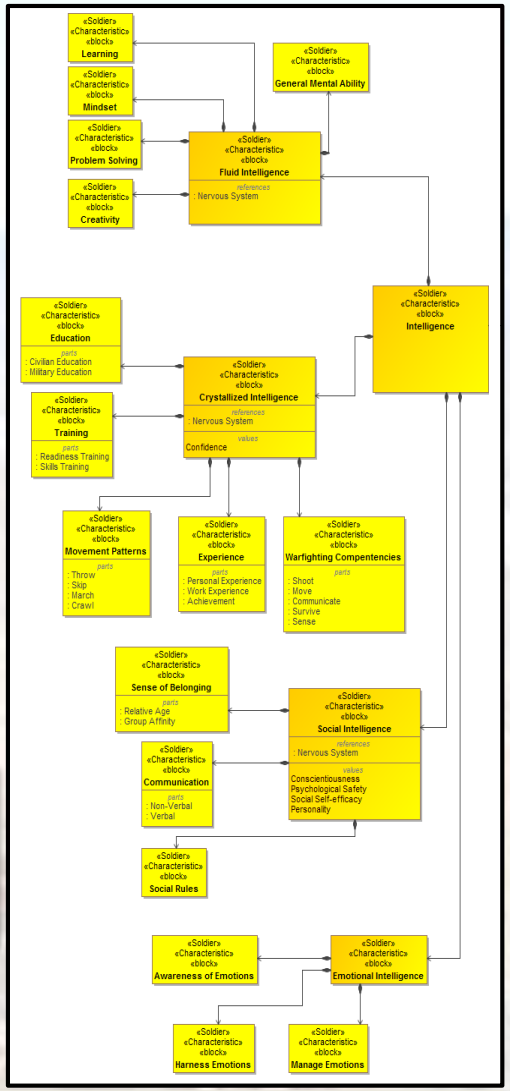
Soldier Behavior



Soldier Behavior:

1. Voluntary (i.e., cognitively founded)
2. Reflexive (i.e., “hard-wired”)

Soldier Intelligence



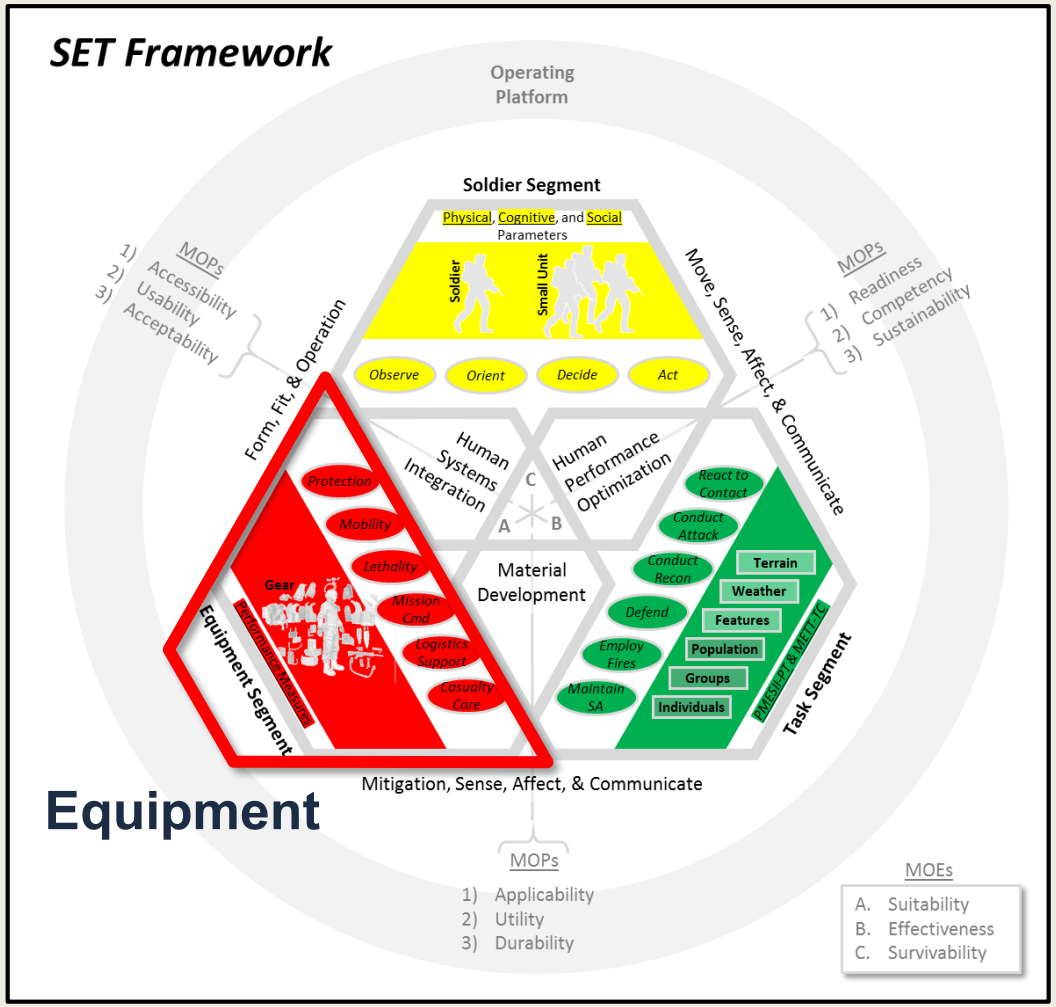
Soldier Intelligence:

1. Fluid (i.e., creativity and learning)
2. Crystalized (i.e., prior skills and knowledge)
3. Social
4. Emotional

Explore the dynamics of Soldier behaviors and intelligence and how these components interact with the Equipment and operational Tasks.

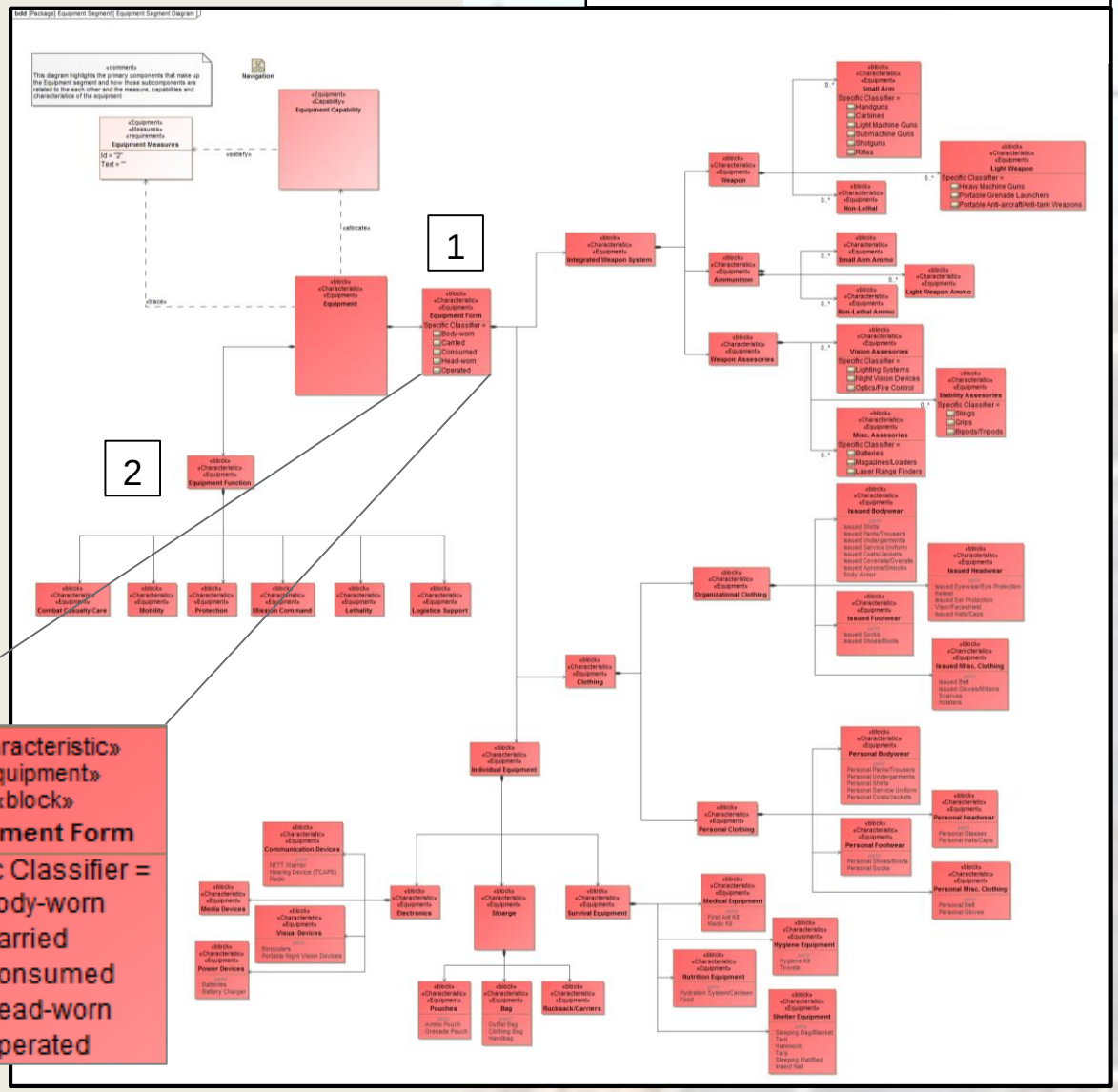
EQUIPMENT SEGMENT OF THE MODEL

Purpose: Define the elements and relationships within the material development dimension, including the type, form, and function of the equipment and how it relates back to its requirements.



SOLDIER AS A SYSTEM: EQUIPMENT SEGMENT OF THE MODEL

Equipment Block Definition Diagram



Two Components:

- *Equipment Form – Integrated weapon system, clothing, and individual equipment*
- *Equipment Function – Combat casualty care, mobility, protection, mission command, lethality, logistics support*

Component Classifiers:

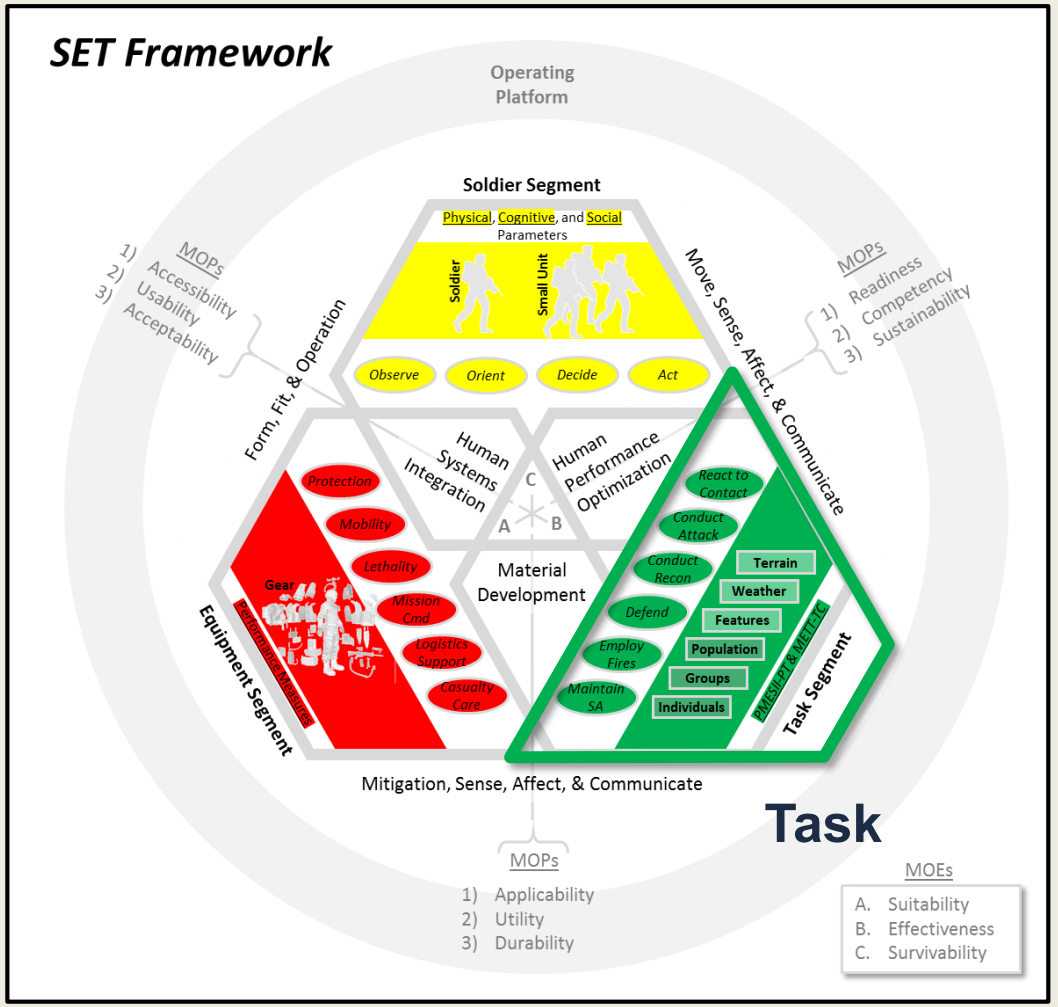
- *Forms of Equipment*
  - *Body-worn*
  - *Carried*
  - *Consumed*
  - *Head-worn*
  - *Operated*

Ports / Interactions (examples):

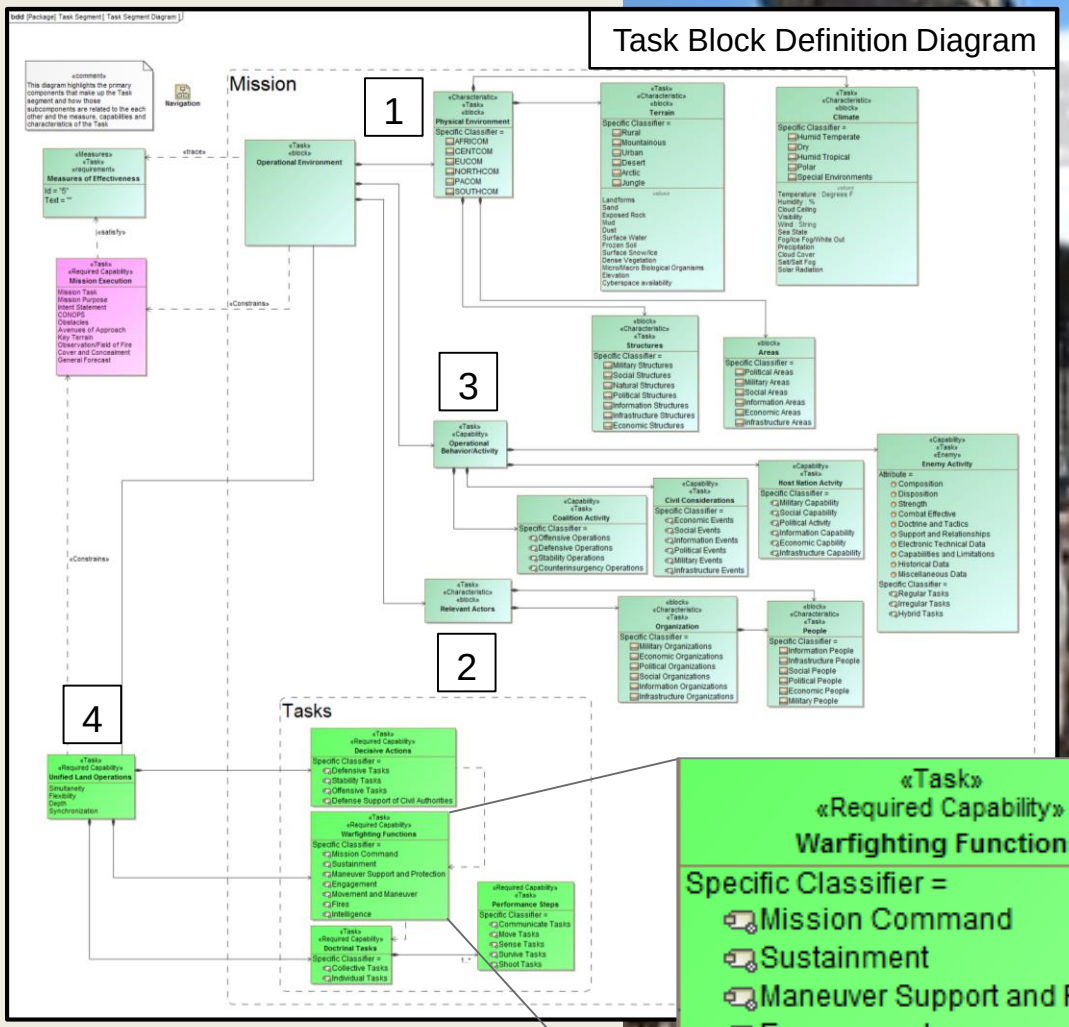
- *Buttstock / Support, Secure*
- *Improved Outer Tactical Vest / Support, Stop, Protect*
- *Rucksack / Provision, Store, Hold*
- *Close Combat Optic / Channel, Import, Allow*
- *Eye Protection / Control Magnitude, Regulate*

TASK SEGMENT OF THE MODEL

Purpose: Define the elements and relationships that the Soldier will encounter within a specific operational environment. This focuses primarily on doctrinal mission elements and parameters.



SOLDIER AS A SYSTEM: TASK SEGMENT OF THE MODEL



«Task»
«Required Capability»
Warfighting Functions

Specific Classifier =
- Mission Command
- Sustainment
- Maneuver Support and Protection
- Engagement
- Movement and Maneuver
- Fires
- Intelligence

Four Components:

1. *Physical Environment – Terrain, climate, structures (man-made or natural), and regional areas*
2. *Relevant Actors – Organizations and people*
3. *Operational Behavior and Activity – Coalition, host nation, and enemy activities, along with civil considerations*
4. *Unified Land Operations – Characterizes decisive actions, warfighting functions, and doctrinal tasks*

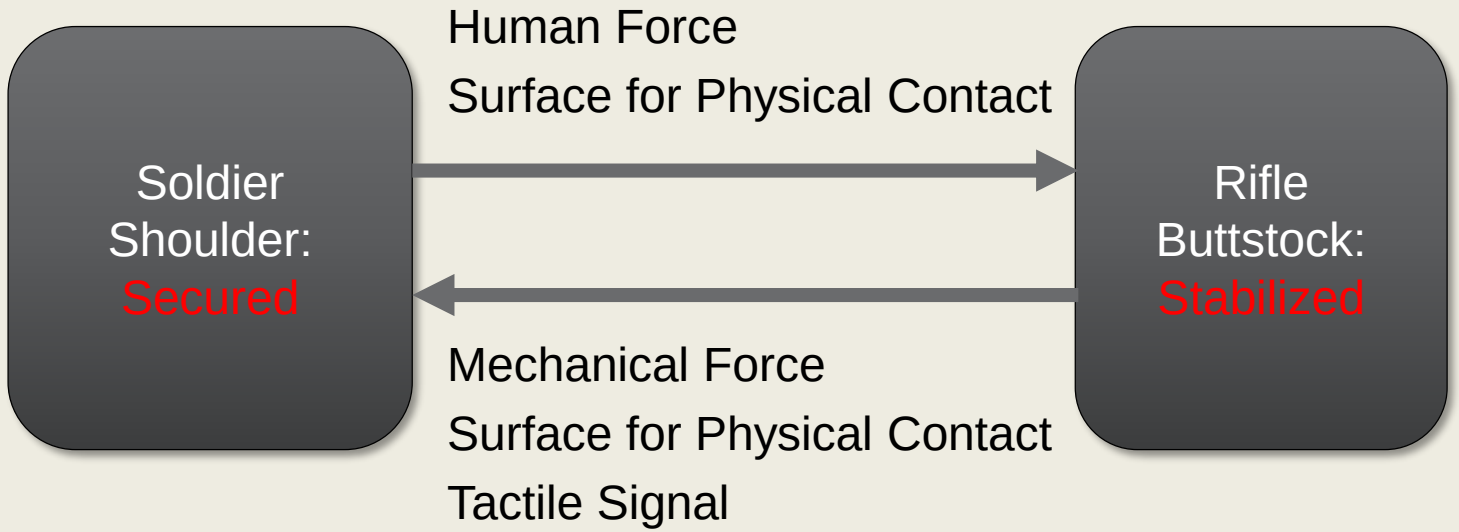
Component Classifiers:

- *Types of:*
  - *Terrain and climate*
  - *Physical structures and areas*
  - *Groups and personnel*
  - *Operational variables (HAMO)*
  - *Operational activities*
  - *Threats and actions*
  - *Tasks and functions*

SOLDIER SYSTEM INTERACTION APPROACH

Purpose: Standardize methods and elements to depict the relationships between the Soldier, Equipment, and Task segments of the SaaS model.

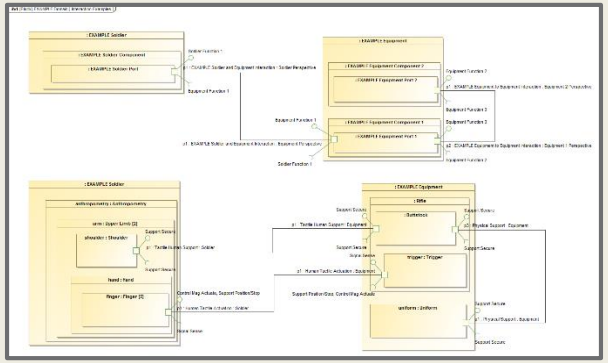
Interaction: Soldier Shoulder to Rifle Buttstock in an active “engagement” position.



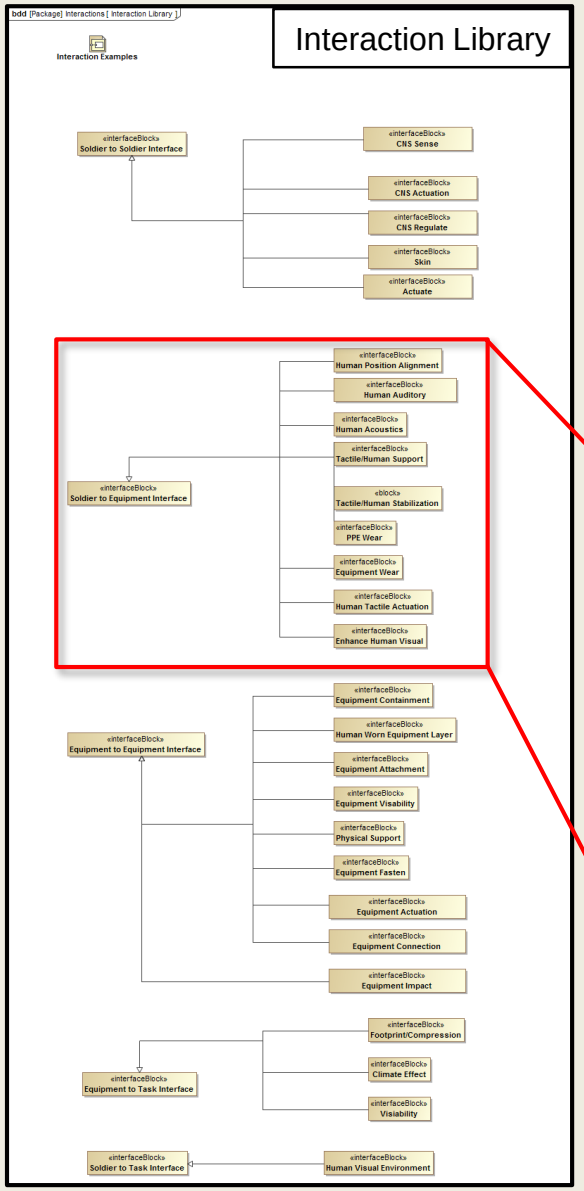
Otto K and Wood K. Product Design: Techniques in Reverse Engineering and New Product Development, 1st Ed. 2000.

SOLDIER SYSTEM INTERACTION APPROACH

Implementation of Relationships into SysML

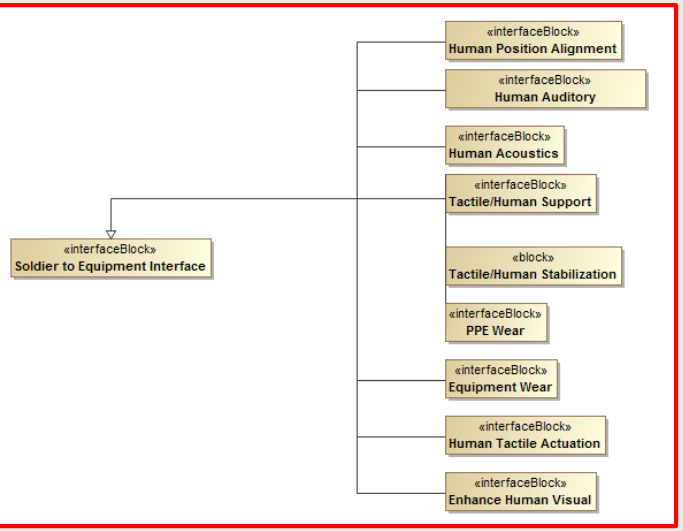


Interaction Library



Approach to Capture Relationships in SysML:

- Represented the interaction information in SysML as model elements.
- Created a library of common interactions which consisted of reusable relationships.
- Provided a reference of the details of the interaction mechanism that the database will leverage for their configuration building.



Describe a wide array of SET relationships using Interaction Library.

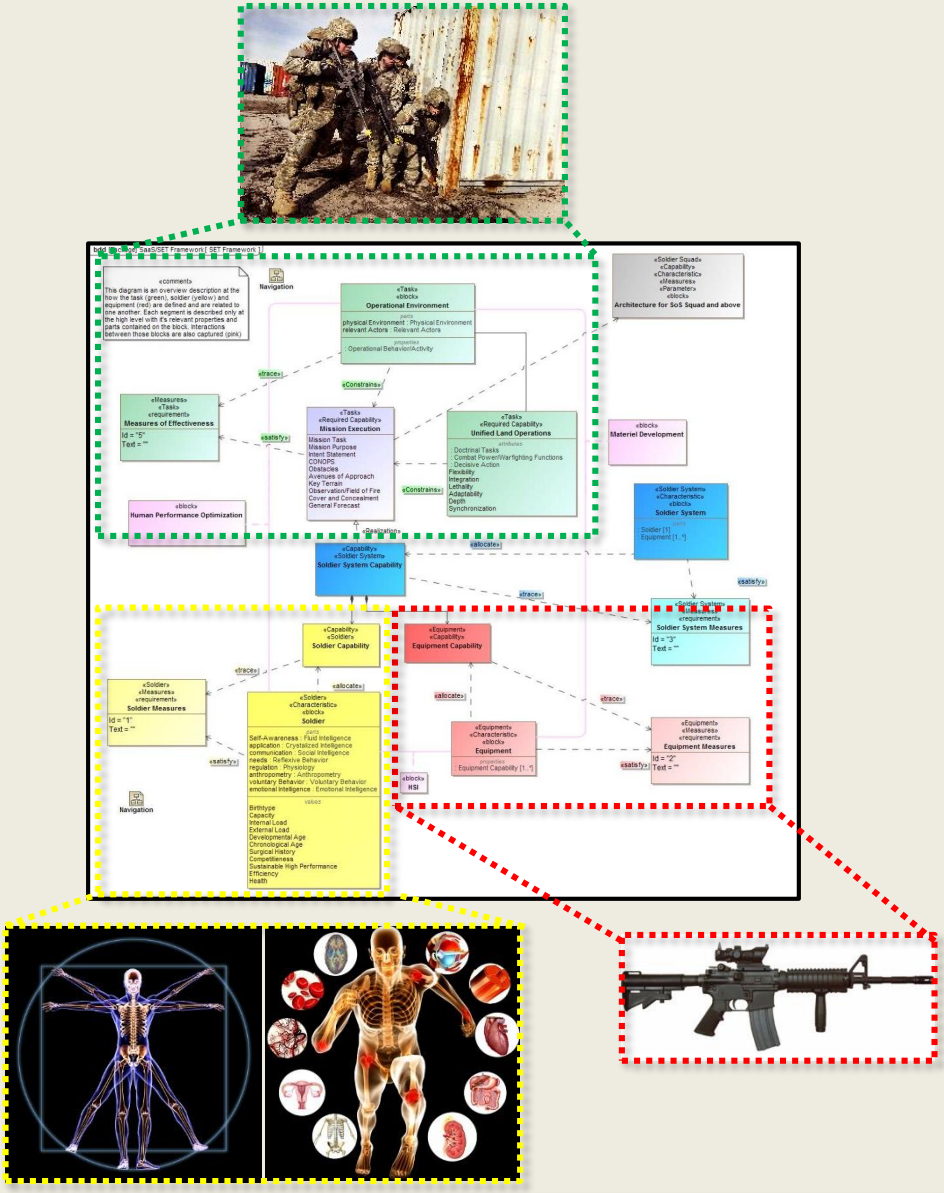
Otto K and Wood K. Product Design: Techniques in Reverse Engineering and New Product Development, 1st Ed. 2000.

CONCLUSIONS

- A MBSE approach can be used to capture and display the meaningful content and relationships within a complex system of systems (i.e., the SaaS), which include elements related to the Soldier, equipment, and task capabilities.

- Human systems integration aspects are captured to further depict the relationships between the Soldier and their equipment in an operational context.

- SaaS SysML models can be used as a tool to improve decision making through a better understanding of Soldier-equipment interactions, leading to the optimization of future Soldier systems.



ACKNOWLEDGEMENTS

U.S. Army Armaments Research, Development, and Engineering Center (ARDEC):

- Shauna Dorsey
- Frank Torres
- Dana Perriello
- David Chau

U.S. Army Natick Soldier Research, Development, and Engineering Center (NSRDEC):

- David Krasnecky (STO Manager)
- Michael Curry (Draper)
- Axel Rodriguez
- Joseph Patterson
- Roger Schleper (Draper)
- John Turkovich (Draper)

Other Government Agencies:

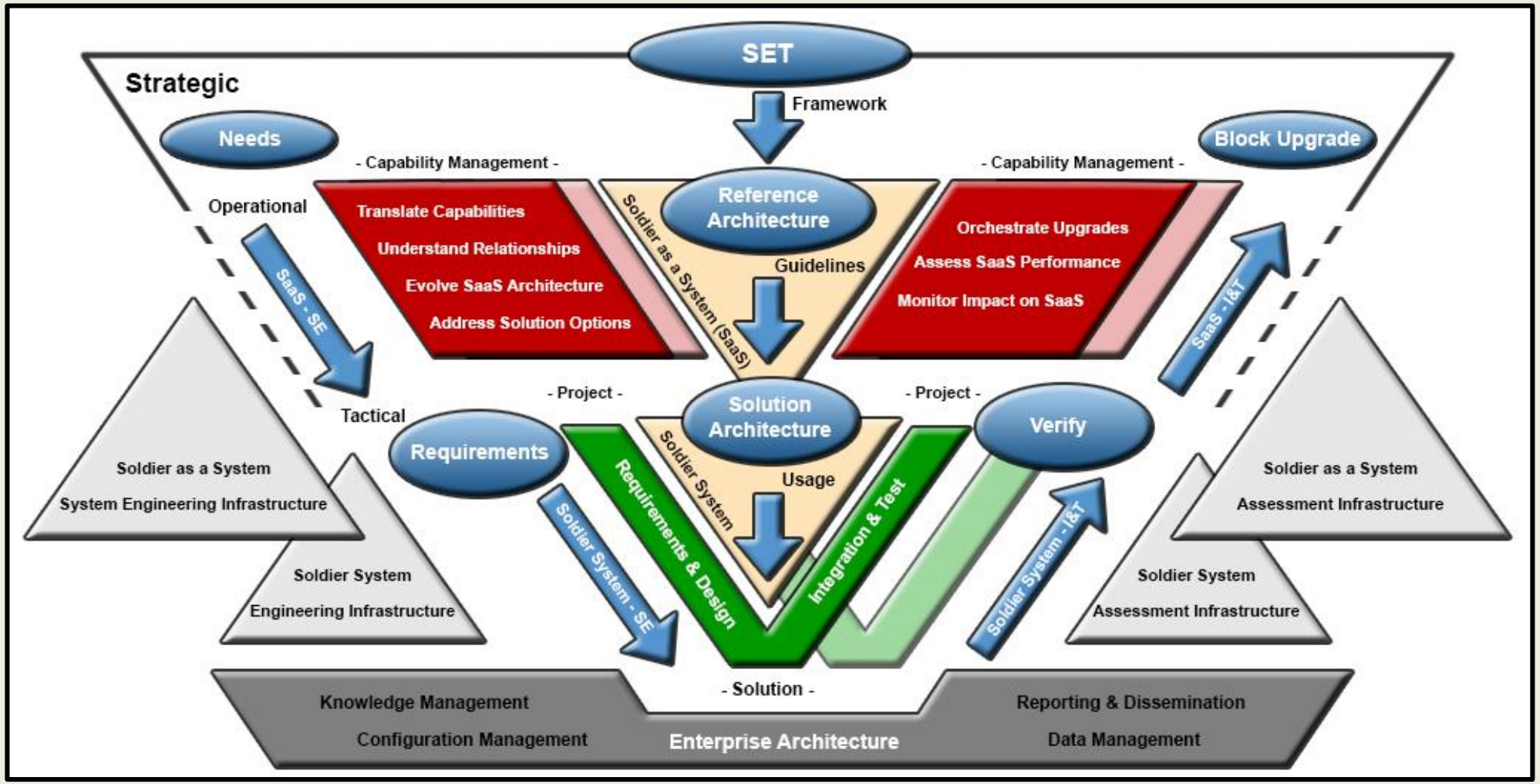
- Army Research Lab (ARL)
- Aberdeen Test Center (ATC)
- Communications-Electronics Research, Development, and Engineering Center (CERDEC)

THANK YOU

BACKUP SLIDES

SOLDIER SYSTEM ENGINEERING ARCHITECTURE

Role of Systems Engineering in SSEA: The SE processes developed for SSEA have been selected to analyze, design, integrate, and evaluate Soldier as a System solutions.



SOLDIER SEGMENT OF THE MODEL

Anthropometric and physiological elements included in the Soldier Segment of the model were obtained from Anatomy and Physiology references.

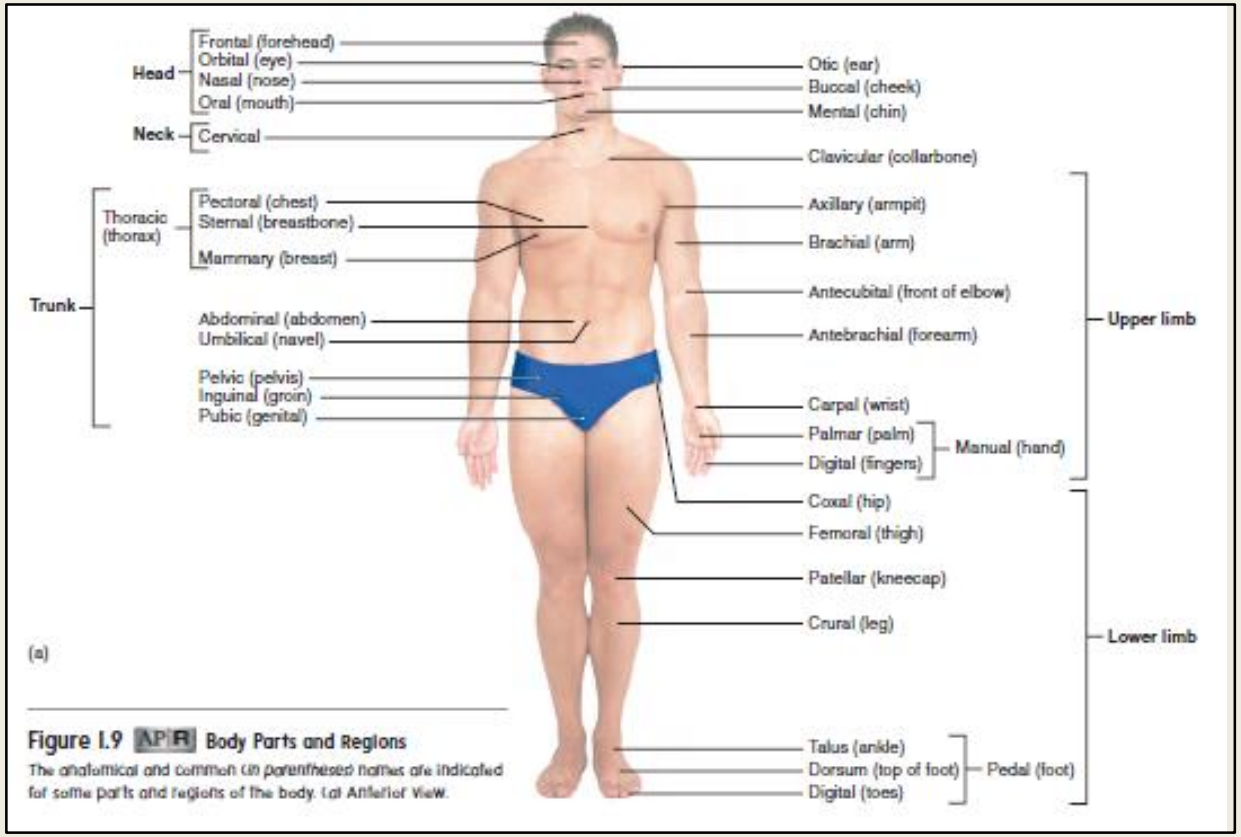


Figure I.9 APR Body Parts and Regions

The anatomical and common (in parentheses) names are indicated for some parts and regions of the body. (a) Anterior view.

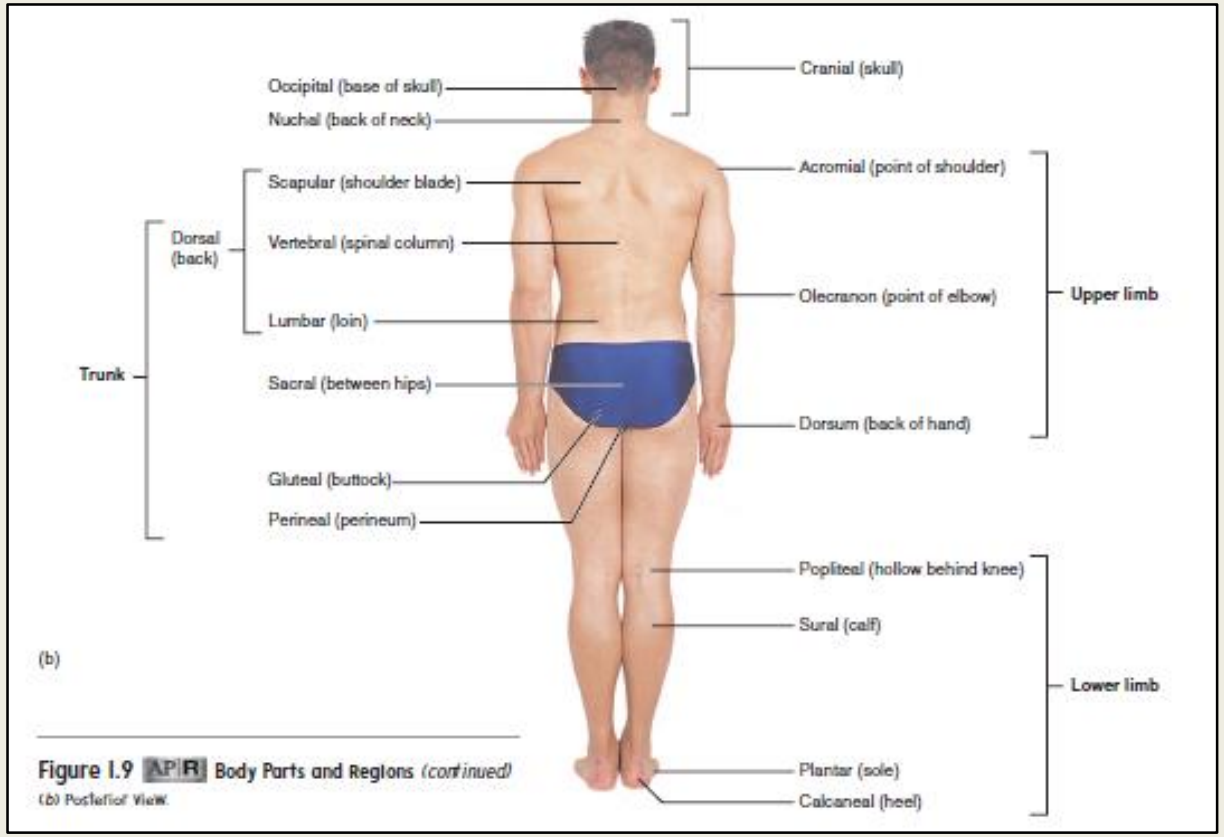


Figure I.9 APR Body Parts and Regions *(continued)*

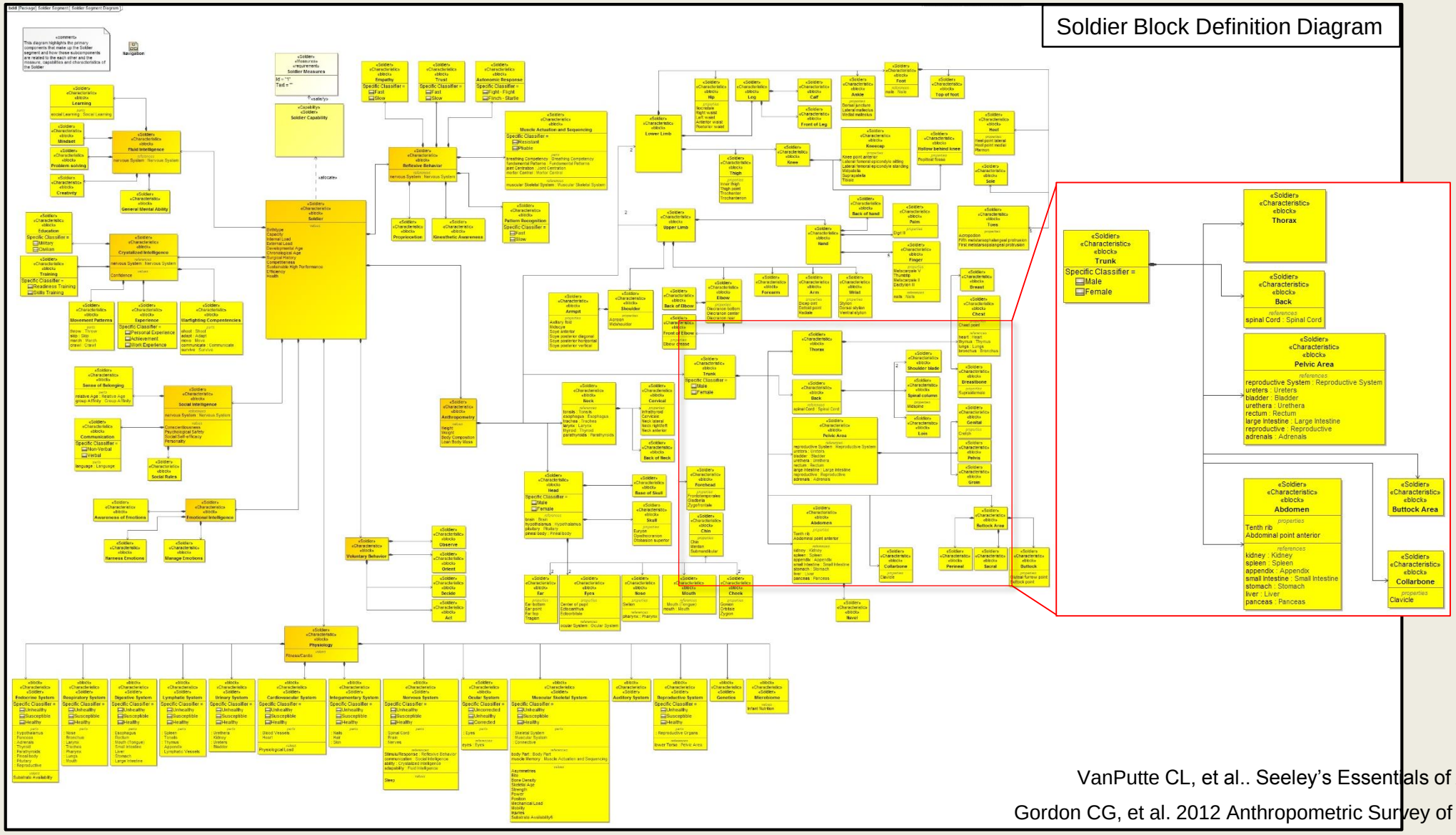
(b) Posterior view.

VanPutte CL, et al.. Seeley's Essentials of Anatomy and Physiology, 9th Ed. 2014.

Gordon CG, et al. 2012 Anthropometric Survey of U.S. Army Personnel. NSRDEC. 2012.

SOLDIER SEGMENT OF THE MODEL

Soldier Block Definition Diagram



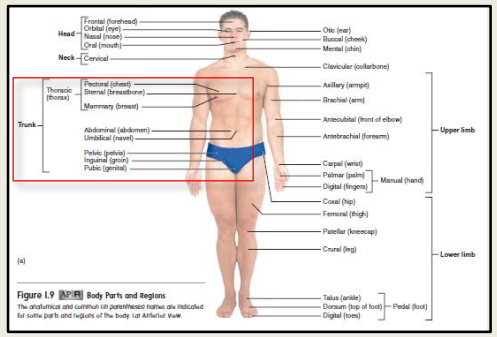


Figure 1.9 APR Body Parts and Regions

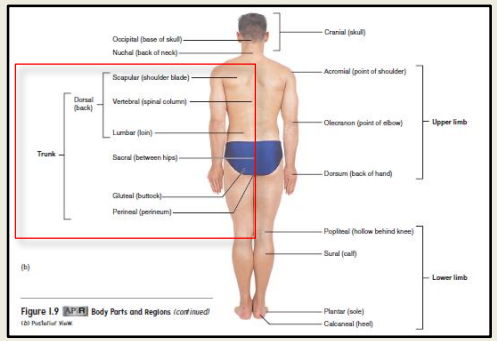
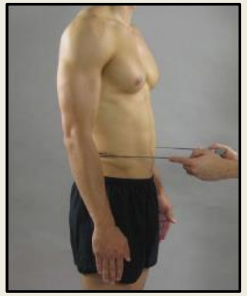
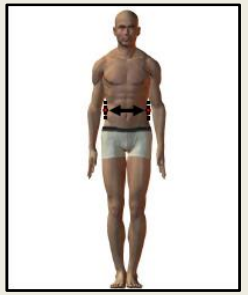


Figure 1.9 APR Body Parts and Regions (continued)





VanPutte CL, et al.. Seeley's Essentials of Anatomy and Physiology, 9th Ed. 2014.

Gordon CG, et al. 2012 Anthropometric Survey of U.S. Army Personnel. NSRDEC. 2012.

SOLDIER SYSTEM INTERACTION DEFINITION

List of Interactions for Target Engagement Operational Scenario

	Start Structure	End Structure (SOI)	Perspective from SOI	Function	Flow class	Basic Flow	Compliment	Candidate Name of Interaction
S-E	Buttstock	Shoulder	Human	Support, Stabilize	Material	Solid		Tactile/Human Stabilization
					Signal	Status	Tactile	
					Energy	Mechanical	Force	
	Shoulder	Buttstock	Equipment	Support, Secure	Material	Solid		
					Energy	Human	Force	
	Rifle Handguard	Hand	Human	Support, Stabilize	Material	Solid		Tactile/Human Stabilization
					Signal	Status	Tactle	
					Energy	Mechanical	Force	
	Hand	Rifle Handguard	Equipment	Support, Secure	Material	Solid		
					Energy	Human	Force	
	Rifle Grip	Hand	Human	Support, Stabilize	Material	Solid		Tactile/Human Stabilization
					Signal	Status	Tactle	
					Energy	Mechanical	Force	
	Hand	Rifle Grip	Equipment	Support, Secure	Material	Solid		
					Energy	Human	Force	
S-E	Rifle Handguard	Hand	Human	Support, Secure	Material	Solid		Tactile/Human Support
					Signal	Status	Tactle	
					Energy	Mechanical	Force	
	Hand	Rifle Handguard	Equipment	Support, Secure	Material	Solid		
					Energy	Human	Force	
	Rifle Grip	Hand	Human	Support, Secure	Material	Solid		Tactile/Human Support
					Signal	Status	Tactile	
					Energy	Mechanical	Force	
	Hand	Rifle Grip	Equipment	Support, Secure	Material	Solid		
					Energy	Human	Force	

Otto K and Wood K. Product Design: Techniques in Reverse Engineering and New Product Development, 1st Ed. 2000.