What is HMI?

By Major Andrew A. Storey

Human-machine integration (HMI) is "all the buzz" in discussions about the future force. It is a fundamental component of the Transformation in Contact 2.0 initiative, often emphasized in discussions of ongoing conflicts, and an activity that nearly everyone has participated in at some point. Machines have become ubiquitous since the Industrial Revolution and are on track to be a more integral part of our world, particularly in the waging of warfare. As the force is modernized, leadership must be cognizant of—and discerning about—what they want a new system or capability to do for us and appropriately integrate it into U.S. Army formations.

But what does HMI mean? The first two components of HMI are easily defined. A human is a living and breathing person. A machine is defined by the Oxford English Dictionary© as an apparatus that uses mechanical power and has several parts, each with a definite function that together performs a particular task. However, integration is a more complex term. Countless concepts define integration across a variety of disparate fields—from psychology to software. Interestingly, two generic overviews seem to capture the best definition.

The F2 Strategy article entitled "The Hierarchy of Integration" articulates the value of integration from a wealth management firm point of view that can be easily translated to any organization dealing in data.[1] The spectrum of integration in the context of the F2 Strategy article is about data processing—the timelier the better. It also discusses which systems process raw data and provide corrective updates based on their methods, with the pinnacle of integration being when raw data is shared with bidirectional (or higher) updates between systems.

The F2 Strategy concept largely focuses on data quality and processing and seems most fitting for "sensor-to-shooter" and "next generation command and control" discussions. While it is an important concept, it largely describes integration between systems and omits the human element of the integration process.

The AltexSoft article, "System Integration: Types, Approaches, and Implementation Steps," outlines several challenges including compatibility issues, security and compliance matters, resource constraints, maintenance and upgrades, and change management techniques that are critical for future force development.[2] Each of these areas should be considered to ensure a smooth and successful human-machine integration effort. This article primarily focuses on resource constraints and the derivative concern of technological limitations. It also discusses different integration models and their respective pros and cons. These example models are simply placeholders for integrated systems and can be translated to current actions in the Army modernization effort.

After examining the aforementioned frameworks of integration and perusing various dictionary suggestions, integration appears to basically be defined as the process of joining systems into one cohesive infrastructure. Therefore, HMI can be defined as the process of joining humans and machines into one cohesive system or unit.

Humans have adapted to new tools and upgrades and leveraged existing technology toward integration at an increasingly frenetic pace. Militarily, integrations equate to the stages of HMI that have enabled fighting formations of increasing lethality. The limiting factor is usually the level of autonomy at which the machine in question is capable. This naturally lends itself to a progression of three demonstrated terms (reinforcement, substitution, and augmentation) and one hypothetical term (replacement).

Reinforcement

Reinforcement is the most basic form of HMI. It utilizes a machine that can do something better than a human can. (For example, a cannon can propel a destructive charge farther than a human can throw it.) This often results in complementary functions between humans and machines, such as those between a tank and its crew. The tank protects the crew and enables an increased range of lethality that reaches farther than the fire team of people inside can accomplish on their own. In turn, the crew provides the prioritized functions (identifying and prosecuting targets, communicating with other forces, navigating complex terrain) that would otherwise require significantly more automation.

Substitution

After significant developments in control interfaces, communications bandwidth, and trained operators, HMI progresses to the stage of substitution. Substitution removes the Soldier from the hazard, enabling safer methods of resolving hazardous situations (such as neutralizing unexploded ordnance with an interrogation robot) encountered on the modern battlefield. However, the level of autonomy exhibited by the system is still a limitation; for example, unmanned aircraft systems that perform surveillance by following set waypoints, or first-person-view drones that target enemy armor but are reliant on trained operators. This stage also represents the first occurrence of "no blood on first contact," a common catchphrase in HMI discussions about humans being removed from potentially dangerous situations that involve the first contact with the enemy.

Augmentation

The next stage of HMI that exhibits significantly more autonomy is augmentation. This concept is similar to that of 'teaming,' where drone systems (attributable automated systems) are directed by a human (not continuously controlled, such as by joystick piloting as with a first-person-view drone) or by its own priorities algorithm in support of a human. The previous mention of unmanned aircraft systems following waypoints is the threshold to this stage.

The effectiveness of augmentation is proportional to the level of autonomy the drone system can exercise. The more independence the system exhibits in finding the easiest way to negotiate the route to its objective, assessing and prosecuting targets, and achieving the desired directed effect, the less input from a supporting human element is required. The current limitation to maximum exploitation of this stage is the insistence on a "human in the loop" (appropriate human judgment before target prosecution). This builds upon the Army's approach to assessing and accepting risk associated with potentially harmful lethal and nonlethal effects. Currently, an all-encompassing table that quantifies risk to a defensible value that a machine could independently evaluate does not exist. The human dimension remains critical for context and for the ultimate command of an operation.

Replacement

The final stage of HMI is replacement. During replacement, humans are completely removed from the hazard and machines are given the desired end state or objective that is achieved by executing tasks within a specified set of laws of armed conflict. The concern is that, at this stage, the enemy might identify and exploit loopholes in these prescribed laws (such as the three laws from i, ROBOT) that inflexible machines will be unable to navigate without human involvement.[3]

While the exact definition of HMI has been nebulous in the past, this framework helps determine the best approach toward the future force formation development of HMI. Establishing the stage of integration that is most appropriate for the specified tasks of a formation helps to govern the levels of interface and investment that are required.

Current fiscal constraints dictate that at some point, things must be assessed as "good enough." Therefore, warfighters and future force developers should strive to clearly define the requirements of proposed technological applications to ascertain feasibility and resource estimations while more rapidly delivering future capabilities to warfighters. ♜

Endnotes:

[1]"The Hierarchy of Integration," *F2 Strategy*, 2 December 2021, <https://www.f2strategy.com/insight/hierarchy-of-integration>, accessed on 13 March 2025.

[2]"System Integration: Types, Approaches, and Implementation Steps," *AltexSoft*, 20 June 2024, <https://www.altexsoft.com/blog/system-integration/>, accessed on 13 March 2025.

[3]Alex Proyas, "i, ROBOT," 2004, Twentieth Century Fox.

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