Confederation of Indian Industry

Integrating Human Centered Design in the Indian Defence Sector

Policy Report

CII National Committee on Design Innovation

2023- 24

Executive Summary

As India is rapidly moving towards a self-reliant future with an emphasis on "Make in India", there is a reciprocal need for the human centric design of defence technologies. The aim of this policy report titled "Integrating Human Centric Design in the Indian Defence Sector' is to present directions in which a Human Centered Design (HCD) engagement can be developed for the Indian defence sector. The report first lists the major challenges in this area that limit the growth of HCD engagements, and then provides thirty recommendations in this regard. The recommendations are presented at various levels of engagement as well as organizations to ensure that HCD is engaged with the Indian defence sector at several layers of abstraction, and with multiple stakeholders. It emphasizes HCD integration for Indian defence as a sectoral challenge. In essence, the policy brief presents a sectoral viewpoint that accounts for the aspirations of the country, business interests, end-user goals, and values of the defence forces.

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1. Introduction

With the emphasis of "Atmanirbhar Bharat" and "Make in India", the defence sector has seen growth of various private industries as well as a change in the outlook of the various Defence Public Sector Units, Defence forces and the government. This enormous emphasis has resulted in the growth of technology and technological offerings in the country. While there is an extensive potential for the technological revolution underway, there is also the necessity to recognize the human contribution to technology. Specifically, the aim of this policy document is to address human-centered design as a contributor to the defence sector in India. In short, this policy brief proposes that along with "Make in India" and "Atmanirbhar Bharat", there is also the need for *"Integrating Human Centred Design for Indian Defence"*.

This elaboration of the Human Centred Design (HCD) is important because the usage of technology is by defence personnel. The single-minded pursuit of technological design leads to unusable technology to which the end-user (e.g. soldier) has to adjust. This adjustment, ultimately, results in long-term adaption of the users to poorly designed human-centric equipment (often, defence equipment has an operational life of 10-15 years), affecting the combat capability of the forces. In the future, operational readiness will have to be supported not only by the perspective of technological readiness but also from the viewpoint that technology should be human-ready and usable to leverage and support combat experience. Along with combat experience, a human centred viewpoint should also support defence personnel in various roles (such as maintainers, testers, amongst many others), in the entire lifecycle of the various technological systems. *In short, there is a need to support human experience in systems design that will contribute towards improved combat experience, national productivity, international competitiveness, and other collaborative engagements between various stakeholders ranging from defence integrators to startups.* Therefore, this policy report is written with a sectoral viewpoint that encompasses the *aspirations* of the country, business *interests*, end-user *goals*, and *values* of the military.

In addition to the above, several related challenges abound in the defence sector, which limits the entry of HCD. These include a lack of awareness about HCD offerings and capabilities for providing value to various stakeholders. Oftentimes, the HCD output is either labeled as "aesthetics" or devalued as "obvious", with the primary emphasis provided to technological design. This aspect also results in a lack of understanding and use of metrics that support usable HCD-based output in the form of products, services, and

systems. This issue, concomitantly, results in a lack of human integration in the system lifecycle. At the same time, HCD-oriented education has often developed as separated from engineering design in the country, resulting in a lack of a common ground where HCD can easily be integrated by various manufacturers and technologists. Therefore, there is a need for an institutional basis that supports HCD in its various manifestations in the defence sector. Thus, this policy brief takes a sectoral approach to HCD engagement in Indian defence. This will ensure that all aspects of design are seriously considered by a broad breadth of engagement not only with organizations and institutions but also with how the internal processes and practices in these can be engaged. The report also avoids focusing on one single individual, team, or organization and moves beyond it in order to engage with a broader evaluation of how the various stakeholders can be meaningfully engaged with a human-centric approach.

The rest of this policy document develops the need for an HCD approach in the defence sector in India. Towards this end, it describes HCD and its necessity for the Indian defence sector (Section 2). In Section 3, the challenges and barriers to incorporating human-centered design are discussed in detail. Section 4 develops steps in the form of recommendations that can be used to create a more vital human-centered design ecosystem. The policy brief concludes with future opportunities (Section 5) for HCD in the Indian defence sector.

2. What is Human Centred Design for defence?

In order to engage HCD with the defence sector successfully, there is a need to understand the sector itself along with the manner in which HCD has developed globally in the past five decades. The defence sector is a complex systemic sector that involves designing technologies for people as well as supporting change in people's capabilities through training. Thus, at an abstract level, both the human and technology have to be jointly optimized. In addition, the performance of the soldier on the field is shaped by a number of personal, environmental, situational, and extra-situational factors beyond the immediate realm of operations, including the constraints imposed by teams, organizations, and military doctrine. Therefore, when we have to design for the soldier in context, we are taking into account the performance-based challenges of the human as well as the sectoral challenges of Indian defence. This outlook poses a different provocation for design as it has traditionally developed in India. In other words, we are designing for *sociotechnical systems* that involve a consideration of both people and technologies, as hybrids, enabling the movement beyond the realm of artifacts.

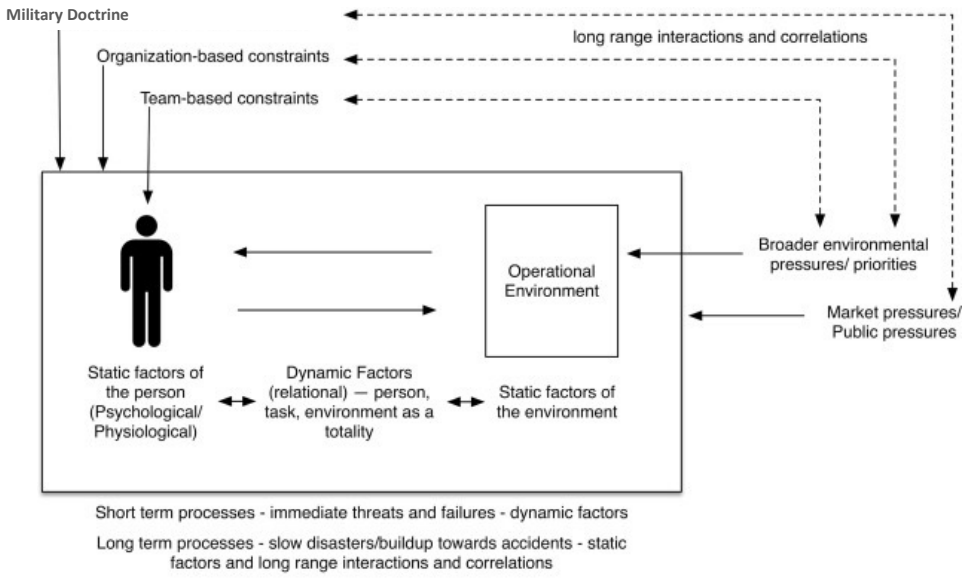

Figure 1: The full breadth of the complex sociotechnical systems of which the end-user is a small part. HCD for Defence often requires an understanding of the overall sociotechnical system to design for the end-user

The study of sociotechnical systems grew as a part of the discipline of Human Factors. Human Factors is an area of study and design that takes into consideration the capabilities and limitations of people while designing for their well-being, productivity, and safety. Human Factors grew forth in a significant manner globally in defence during the interwar years of the World Wars and also WW II. In the 1980s onwards, with the use of computers, there was a prominent growth of Human Computer Interaction and Interaction Design as disciplines. Finally, in the past two decades, with the upsurge in systems engineering concepts and the need for design for complex sociotechnical systems, defence forces worldwide have started to invest in understanding how to leverage HCD with systems engineering in the form of Human Systems Integration.

Due to these large-scale disciplinary changes occurring globally, in order to successfully integrate HCD into the Indian defence, there is a need to move beyond the traditional design discipline of industrial design towards a more significant category that starts from the viewpoint of the human.

This human-centric approach starts with the people first and moves towards technology. This viewpoint is thus in contrast with the technologically centered design, which starts with technology first and then searches for a connection with humans. Currently, due to the intensive technology development, the Indian defence sector is

dominated by technology-centered designers who are primarily engineers or belong to related subsidiary disciplines. As a result, they have a limited understanding of designing for humans or using tools and techniques that support this approach. Therefore, there is a need for HCD as a discipline to be carefully balanced with technology-centered design in Indian defence.

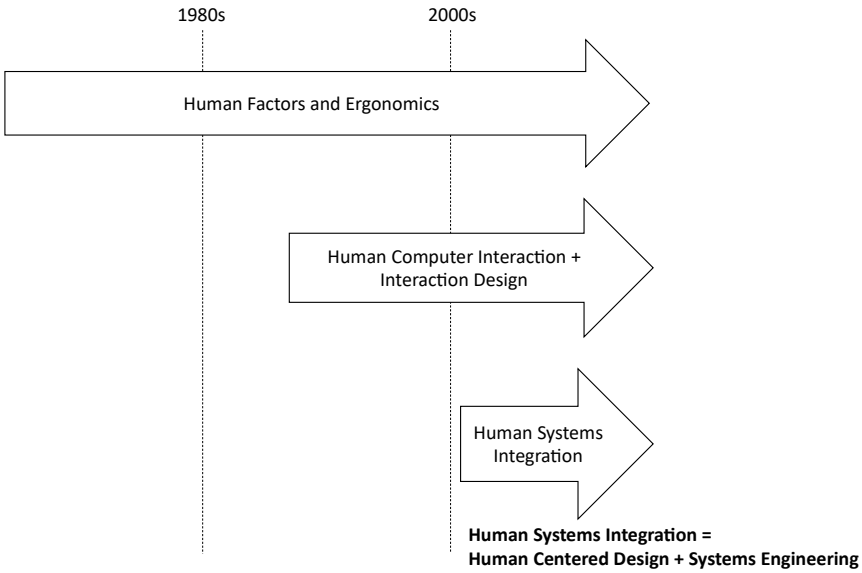

Figure 2: The landscape of the current origins of HCD for defence

A related challenge is the nature of the end-user itself. Unlike defence most civilian sectors, the defence sector deals with a highly specialized "morale and the will to fight" and an adjusting population that will not complain despite any hardships. The soldier who has a gun will fight; the soldier who does not have a gun will also fight. As a result, from the viewpoint of human centric design, poorly designed and unusable products continue to be accepted and used by the forces. The cost saved on removing HCD considerations in defence products is paid by the end-user's ingenuity. In short, If we have well-designed products, then the soldier can concentrate on the battle and not compensate for the technology. In this milieu, the key challenge is not only to emphasize HCD as providing value to combat productivity but also to emphasize that HCD will impact the overall defence sector in terms of production, deployment, operation, maintenance, and decommissioning.

HCD, in defence should be characterized as a *hypernym* that encompasses the sub-disciplines of interaction design, service design, strategic design, and speculative design, amongst others. These different design-oriented disciplines will have to be taken together with the disciplines of Human Factors and Systems Engineering for a coherent and symbiotic growth of design in the defence sector. In the rest of the policy report, HCD will

serve as an encompassing category that considers different viewpoints within the design while recognizing that they together address and design for the human.

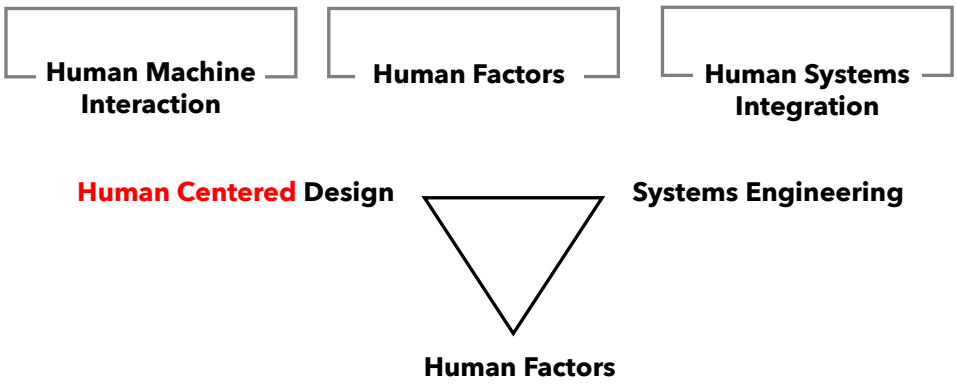

Figure 3: Need for a balanced understanding of HCD in Defence

In addition, a few notes are required to understand the Indian defence sector in order to properly engage HCD. Since the inception of the establishment of defence technological setups in India, the defence sector in terms of design and production was conceptualized as a government-driven sector (with government-owned R&D labs along with manufacturing). These R&D labs, as well as industries, are primarily staffed with scientists and engineers who have been involved in indigenous development, as well as technology transfer from other countries. In addition, defence acquisition and procurement of technologies and systems from foreign countries have also been a mainstay in the defence sector in India. With the change in the outlook towards greater self-reliance, this sector has opened up for private industries.

The defence sector in India is currently in a rapid state of flux with a change in the roles and activities of the government-owned labs, public sector defence industries, private defence integrators, as well as MSMEs and startups. Within this milieu, the role of HCD has to be charted for an overall growth of design in the entire sector. With this viewpoint, the current policy brief takes a sectoral approach that goes beyond individual industries and organizations to take into account a holistic basis for implanting HCD into the Indian Defence sector. Based on the existing state of Indian defence and global changes in disciplines under the purview of HCD, the next section outlines the challenges and barriers to HCD inclusion.

3. Challenges and Barriers for incorporating HCD in the Indian Defence sector

The previous section provided the need for and basis of HCD in defence. The current section will highlight some significant challenges and barriers to engaging with HCD. In all, twelve challenges that beset the Indian defence sector are provided. These challenges will serve as the basis for the policy recommendations for supporting HCD to ensure usability, productivity, safety, and international competitiveness.

1) Everyone is a Human Centred Designer and a Human Factors Expert in Defence:

A challenge with the prominent perception of design is that it is "obvious", "simplistic", and "common sensical". Often it is given low value and priority with the claim that anyone can do it as it is not "technically" or "mathematically" sophisticated. At times, the design disciplines are swept aside under the label of "aesthetics" or "surface treatment".

Similar to design, human factors, specifically the aspects that involve qualitative human experience, is relegated to the status of being obvious, in contrast to the technically sophisticated quantitative measure of human performance. One reason is that the Indian education system is prominently driven by science and technology, the other reason is that the design disciplines never reached a critical mass similar to that of engineers in the country, in order to assert their epistemic distinction for that of engineering.

Further, design output is seen as "obvious" after the act of creation. People may have seen various designed artifacts elsewhere and can replicate them. However, the process of form-giving through creative imagination, as taught to designers, is not adequately valued or given the same accord as the technical prowess of engineers. In other words, people do not recognize that replicating is easy after being creatively visualized. However, the process of creative envisioning still remains a major challenge and is not always obvious to non-designers.

A similar issue exists for Human Factors as a discipline. People, in general, think that they have a grasp of "factors of the human" because they can think and reason about themselves and others. In this perception of human factors, it is not recognized that human factors is a scientifically rigorous discipline. Similarly, anyone who has gone to through an undergraduate education in design will recognize exercises in training the hand and the eye or of visualization strategies. Therefore, in a technology-dominated sector and with a reduced public perception of design, it is not surprising that technologists can brand themselves as human-centered designers despite not having the proper rigorous

background training in design. Therefore, the first key barrier is that HCD needs to be recognized and institutionalized in the defence sector to be a viable generator of value.

2) *Lack of awareness of the role of HCD and the value of a designer, along with the prevalence of "silent design":*

The defence sector is a technologically dominated sector with a primary emphasis on the functioning of engineering products. As a result, avenues for HCD in the form of Human Machine Interaction design or industrial design is considered as an afterthought; primarily, the emphasis is on getting the technology "right". As a result, the end-user interaction is often created by engineers who may have limited or negligible knowledge of HCD principles, tools, and techniques. As a result, while an interface or a product may be created, it will not be human centered. This is because of the prevalence of "silent design". In the late 1980s, Gorb and Dumas (1987) conducted a study on design activities in organizations in the United Kingdom. They found that oftentimes, "design is by people who are not designers and are not aware that they are participating in design activity" (Gorb &Dumas, 1987, p.150). They labeled this phenomenon as "silent design". Silent Design is quite prevalent in Indian defence organizations where the prominent design work focusing on humans is conducted by engineers. In the defence sector, due to a lack of awareness of the differentiated role of the human centered designer as opposed to the design engineer, the final output results as a manifestation of "silent design".

3) Lack of HCD offerings and capabilities for providing business value:

Along with the lack of awareness of the role of a designer, there is a lack of awareness of the range of HCD offerings and capabilities for providing value. The traditional sub-disciplines of design have been in terms of communication design and industrial design, with newer sub-disciplines of service design, system-oriented design, and strategic design opening up avenues for designers. These various newer sub-disciplines are widely adopted in multiple sectors globally. These include design inputs in informing product and organizational strategy, such as in the case of Samsung (Yoo & Kim, 2015). However, in the Indian Defence sector, traditional sub-disciplines such as industrial design have not been able to make headway into the government laboratories involved in the design for the end-user. The real problem is that in the defence sector, someone commissions the product, and someone else uses it. As a result, a design that promotes usability and end-user satisfaction may be lost in the plethora of final designs that are cheaper and may not be conducive to the work activities. As a result, there is a need to create awareness of best practices and return on investment for the services of a designer in the defence sector. Currently, multiple studies conducted globally (e.g., Schwartz, B., & Dodson, 2021) have attested to the value of HCD in defence projects, but they have not circulated into the

conjoined psyche of the stakeholders in the defence sector in India.

4) Lack of separation of design from development and its subsequent HCD-based integration:

In most systems development in the country for defence, engineers have been the prominent workforce. As a result, they have aimed towards the creation of working prototypes and scaling it up for development. While this approach promises results for technological components, the HCD prototypes are not provided in a similar accord, partly due to the previous two challenges. In addition, due to the lack of awareness of HCD principles, tools and methodologies, learning to use tools such as computer-aided-design (CAD) software or GUI programming frameworks (such as QT) is equated to human-centric design. This serves as the barrier to HCD in the engineering-dominated defence sector, and there is a need for separating design from development as separate phases. However, at the same time the design should be created with a view towards the ultimate development. This will ensure that HCD-oriented outcomes are retained without being confounded with engineering design-dominated outcomes.

5) Lack of awareness of understanding of the approach of user engagement (user studies, work analysis, activity analysis, and understanding the end-user mental models):

This challenge is related to the first two issues and deals with the lack of understanding of the fundamental orientation of HCD and how it is used in practice to design for the end user. Designers use a plethora of techniques to qualitatively grasp the end-user viewpoint and mental models. This whole approach falls under the class of techniques known as user studies, work analysis studies, and other related avenues. The designers then use these insights to create forms that support the end user's thinking process. These user studies and work analysis studies cannot be simply reduced to "asking the user". Asking the user is not enough. Users are not typically trained in creative approaches or lateral thinking techniques that create the final form of the design. Therefore, even though the end-users have been asked about their opinions and insights, human centered outcomes may still not manifest.

6) Lack of understanding of HCD and its impact on innovation and international competitiveness:

A lack of HCD affects the creative manifestation of the final end product. This results in sub-standard innovation. For example, consider the following case where there is a lack of Human centred designers. Due to this issue, the onus rests on the engineers and the "end-users" to design a product. For example, in case of the cockpit design of an aircraft,

pilots may provide inputs or even design the HMI of a cockpit, which is then given directly to the engineers for development. These engineers can easily code whatever the pilot has created in the form of HMIs. Due to a steady reliance on defence imports in India, pilots who are trained in various other internationally-created aircrafts would end up deriving insights from those other HMIs. As a result, when feedback from several pilots operating different aircrafts is taken, then the good features of other aircraft HMIs enter into the to-be-designed HMI. However, in this case, the innovation and international competitiveness suffer, as one will always have to wait for the other aircraft designers to innovate on their HMIs so that these designs can then "inspire" the design of the target HMI. As a result, while the target HMI will have the best features of all existing HMIs, as an innovation, the target HMI will always lag behind. In addition, user experience is not only limited to the development of what appears on the screen of an HMI but also requires a total conception of the interaction of humans and technology. The lack of HCD in the technology development process results in a lower standard product from the viewpoint of HCD and affects its international competitiveness.

7) Lack of understanding of basic knowledge-based concepts (crucial for the defence sector) and their application to achieve value from HCD:

This challenge stems from the manner in which the design professions are currently manifested in the country and the lack of a comprehensive development of Human Factors approach in India (Kant, 2022). The main issue is the need for comprehension and operationalization of basic concepts from human factors, into the currently exisiting design profession as it has developed in the country. While physical and physiological ergonomics is prominent in the design of products, a similar claim cannot be made about cognitive and organizational human factors. A prominent example is the concept of "Situation awareness (SA)". SA and the Design for SA (Endsley, Bolte & Jones, 2003) is a prominent area of research in the defence sector that is well-established globally in the defence sector. However, a designer from Indian design universities may not be aware of these basic concepts as it does not enter their vocabulary when they are designing artifacts for civilian use. Therefore, there is a need for designers to comprehend the basic concepts to use for design in the defence sector as it has developed globally in order to ensure user-centricity and maintain international competitiveness.

8) Need for HCD for Reliability, Availability, Maintainability and Safety:

Engineered systems in the defence sector involve issues of technical reliability as well as ease of maintenance. In addition, the system should be available-on-demand (based on failure rates), as well as be safe for operations. Within this highly technical milieu, HCD can play a very important role that is currently not widespread in the defence sector. For

example, HCD principles and industrial design processes can be used to create easy-to-reach maintenance ducts, accessible door handles, or modular equipment. This will ensure that anthropometric measures and workspace design principles are adhered to, resulting in less fatigue, safe usage, and a general decrease in musculoskeletal disorders (MSDs). In addition, human factors and environmental design will help in the design of workspaces that are not overly noisy, humid or present detriments to the end-users due to how they have been created. Similarly, HMIs can also be designed for Health and Usage Monitoring Systems (HUMS) of tasks and other large equipment. Using HCD principles can help us in information design for analytics and insight discovery. These aspects of HCD have still not percolated in the defence sector in India and remain a vital need.

9) Lack of Human Systems Integration (HSI) and Human Readiness Levels (HRLs):

Currently, due to the lack of a strong base of human factors, there is a lesser uptake of Human Systems Integration (HSI). HSI is a technical, management, and design-orientated discipline that takes into account all human-related considerations during the design, development, testing, production, deployment, and decommissioning of systems. HSI is a well-developed approach taken up by various defence agencies in the international arena. Typically, HSI processes involve addressing not only the personnel but also survivability and habitability, amongst other vital concerns. Currently, these aspects are not addressed in the existing design discourses in India. In the future, there is a need for addressing and supporting humans in the entire systems lifecycle in complex sociotechnical systems such as defence. This is possible through accounting for Human Readiness Levels (HRLs). The HRL scale is designed to complement the Technology Readiness Levels (TRLs). The main focus of the HRLs is to recognize and account for the artifacts in human-centered teams. Therefore, while a system can be technologically-ready, it may not achieve maturity for human use. Therefore, in order to make systems that are human-ready, incorporation of the HRL scales helps in program management and provides categorical level-based understanding for the design for the end-user. These aspects of HRLs for supporting end users and program directorates need to be incorporated into various system design and development organizations catering to Indian defence.

10) Lack of widespread use of metrics for usability in the defence sector in India:

Due to the lack of sensitivity towards HCD, there is a need for usability metrics that can be used widely in the defence sector. The traditional usability metrics that are present in UI/UX are geared towards civilian applications. There is a need for usability heuristics and metrics that are required for comprehending the operator experience. Cognitive engineering, a sub-field of human factors, provides heuristics and metrics for humans in

complex systems. In addition, several systems usability scales (e.g. Lewis, 2018) have been developed by human factors researchers, and they can be imbibed by designers in India to strengthen the human-centric evaluation, verification and validation of systems in the defence sector.

11) Lack of understanding of the effort required for the design aspect of HCD and incorporation in the systems life-cycle:

Due to the emphasis on getting the technology to work, there is often the desire to leave the HCD considerations to the very end. Two problems occur due to this issue. First, the effort in terms of human-hours is not adequately accounted for, resulting in budget overruns. This occurs typically when the various iterations of the human interface/product/service need to be considered towards the end of the development. Thus, programmers and engineers are left with the technically completed product, but at the same time, they change it to accommodate the human at the very end. This results in unaccounted expenditure that was not completely accounted for at the beginning of the project. Second, there is more design flexibility and less system development cost at the beginning of the project. As a result, technical design and HCD can be adequately and jointly optimized to ensure that various HCD iterations are possible and fit in with the technological conceptualization of the problem. Once the design is finalized, significant development efforts can be initiated without radical changes to both the technical design and the human centered aspects. Thus, the relation between HCD and systems development lifecycle needs to be articulated for the defence sector.

12) Lack of institutional basis of HCD for defence:

The final barrier involves the lack of an institutional basis for HCD for defence. This institutional basis is due to differences in engineering design and HCD programs that provide design education. For example, HCD is provided by traditional design schools such as the National Institutes of Design (NIDs) and design departments of various other institutions, including several Indian Institute of Technology. In contrast, engineering design is the province of the engineering departments of various IITs and comes under the guise of Design engineering or engineering design courses. As a result, there remains a gap between the merging of HCD and engineering design, especially when it comes to large-scale systems design for defence. The HCD-oriented design departments in various IITs have also remained aloof from engineering design (for e.g., Department Designs at IIT Bombay, IIT Guwahati, and IIT Hyderabad, which typically cater to HCD).

Along with the academic institutional rift, the lack of institutional link continues at more mundane levels outside of academia. This is manifested in terms of business organizations (both private and public), as well as defense research organizations. Thus,

there is a need to institutionalize HCD principles, techniques, and methodologies. This institutionalization is needed so that the everyday functioning of design in technological teams incorporates HCD right at the inception. Due to the heavy orientation of science and technology in various funding agencies, HCD and its research and practice still take a backseat. An embedding of HCD into the various civilian business and military agencies is needed to support HCD at a more strategic level of engagement in the country's defence sector.

4. Steps to incorporate HCD Pathways - Policy Recommendations

Given the need for HCD and the nature of the defence sector, this section enlists 30 policy recommendations that can create a sustainable ecosystem in India to support a human-centric future-ready defence sector. While many of these recommendations seem similar, they have been differentiated to ensure shades of meaning on a particular topic. These recommendations range from the formulation of HCD design teams to the inclusion of HCD at a strategic level. Therefore, these recommendations aim to address the challenges and barriers raised in the last section to provide a sustainable inclusion of HCD in the Indian defence sector.

1. Create awareness in the private and public enterprises for the need for HCD and the value it can create for the defence sector. Mass education about HCD principles and practices is a must for all stakeholders in the Indian defence sector.

2. Involve and educate higher leadership in various public and private defence organizations on the benefits of incorporating HCD principles and methodologies in their organizational processes and outcomes.

3. Create multi-functional teams that, along with engineering designers and developers, involve both HCD practitioners and defence Subject Matter Experts. Do not use engineering designers as a substitute for HCD designers. Create a new role of an HCD designer on teams involved in design for defence.

4. Start HCD activities at the inception of the project with an adequate budget to support HCD practitioners throughout the systems lifecycle. Integrate HCD into all aspects of the systems lifecycle to ensure a complete HSI-based unification for all projects.

5. Ensure end-user involvement in all phases of design. End-users should not be confused with the procurers and commissioners of the system. End-users and their worldviews, along with mental models need to be grasped using work analysis techniques. Contextual in-situ studies of end-users should be encouraged. Given the nature of the defence sector, the defence forces should support engagements with end-users and the designers to HCD considerations in the final developed technologies. Industries should also tap into the pool of ex-service people in the country to enable focus groups, interviews and in-depth understanding of end-user mental models.

6. Incorporate HCD-based metrics that account for usability, productivity, and safety along with verification and validation of all HCD-based interim steps of every stage of the systems lifecycle.

7. Develop a joint vision for "HCD in Indian Defence" shared by the government labs, defence forces, and private industries.

8. Develop competency in educational organizations in the Defence sector (such as DAIT, INS Shivaji, MCEME, NDA, amongst others) about HCD. The entire defence educational sector should have a course on "HCD for Defence" as a part of their curriculum. This will enable sensitization among the forces so that they can then ask for the HCD-based equipment in operational settings. Specifically, they will know exactly what to look for in well-designed products that the defence forces acquire.

9. Design schools in India should cater to courses in design for defence with the syllabus derived from HCD, Human Factors and Systems Design. Design schools should be developing this curriculum with subject matter experts from all the aforementioned human-centric areas along with the forces.

10. All engineers from engineering institutions such as AICTE-based engineering colleges and IITs should have a course on HCD or Human Factors for defence to enable them to understand the challenges of HCD in defence. If this course is not a part of the curriculum, then these institutions and boards can provide online resources for mass-education.

11. Funding agencies may consider funding research and development on topics related to HCD. These include the ARDB Systems panel, Naval Board, amongst other government defence funding agencies. These funds should support and enable futuristic design projects (e.g., concept design of cockpits of aircrafts), as well as support mundane human-centric design applications (e.g., anthropometric design

of seating in combat aircrafts).

12. In conjunction with the last point, HCD-based approaches should be developed for the defence sector to develop solutions for various social and environmental conditions in which the forces operate. Issues of survivability, comfort and safety are a concern that HCD designers should address. These include border conditions in extreme weather conditions in the Siachen glacier or socially sensitive conditions of the various borders with neighboring countries in the northeastern region of India.

13. Government agencies such as DRDO should create a specialized lab for HCD, Human Factors, and Human Systems Integration that will assist in all aspects of HCD-based support in the system's lifecycle.

14. The newly opened DRDO-Industry-Academia (DIA) Centers of Excellence should have a vertical supporting HCD, Human Factors, and HSI (currently, the DIAs are heavily- geared towards technology: https://www.drdo.gov.in/adv-tech-center).

15. Evaluation agencies and programs such as IDEX and TDF should adopt HRLs and adapt them to their own needs of project management for evaluating human readiness, along with the TRLs for technology readiness.

16. Evaluation agencies and programs such as IDEX and TDF should involve HCD and Human Factors Experts for curation, sanitization, and reformulation of their project requirements, problem statements, and calls for proposals. This will enable the applicant industries to streamline their applications towards a proper conception of HCD right at the formulation stage.

17. HRLs and HCD criteria should be incorporated into all projects that involve end-user engagement. Organizations should ensure that the HCD dimension is added to their existing development methodologies and processes (such as agile, concurrent engineering, etc.). Defence Integrators, both private and public, should aim towards an organizational thrust on the incorporation of HCD for enhanced system delivery.

18. Government defence agencies, ranging from research to acquisition, should incorporate HCD principles and practices at a strategic level to enhance the quality of service, delivery outcomes, and end-user support in all phases of their technology acquisition, design, development, maintenance, and decommissioning programs.

19. Startups and MSMEs who are involved in developing defence technologies that may involve end-user engagement should account for HCD efforts in their various

budget heads in projects. In turn, the funding and facilitating agencies should specifically ask for HCD activities to be supported by both startups and MSMEs.

20. In order to ensure change management for human-centric outcomes, organizations should form internal teams along with HCD experts (acting as facilitators). These meetings will facilitate change management in defence organizations to ensure HCD activities as part of their core competencies.

21. Organizations, both public and private, should ensure that HCD activities and technical design activities are jointly optimized for human-centric outcomes of services, products, and systems.

22. Organizations, both public and private, should ensure that HCD-based outcomes are finalized and end-user acceptance is gained before development begins. This will reduce endless changes to the design once the development phase has begun.

23. System designers (private and public), as well as the end-users (defence forces), should both ensure that HCD activities support the design for reliability, maintainability, availability, and safety at all phases of their systems lifecycle. This will ensure a reduction of operational costs in maintenance and decommissioning. This will also ensure that human factors in maintenance becomes a human-centric activity rather than a purely technical activity.

24. Defence equipment should be designed taking human capabilities and limitations into account. This involves considering both Indian men and women to support the accessibility of both genders in the forces.

25. An important aspect of HCD is in terms of designing for the human scale in terms of body measurements as well as static and dynamic human performance measures. While the science of anthropometry addresses these issues and a number of anthropometric tables have been created for the Indian population, a more robust and diversified set of anthropometric measurements can be created for the defence sector aiming at detailed measures (e.g. phalanx length) to improve the granularity of anthropometric data. Due to the sensitivity of the information, the DRDO labs can act as the custodian and information can be shared with the design teams when they are working on government projects. In addition, the Society of Indian Defence Manufacturers can commission a database for such measurements based on data gathered from ex-service people and can be shared on a restricted basis for their member industries.

26. SIDM members and large private defence integrators should endeavor to develop their own R&D facilities for human performance, human factors, and human-centered design.

27. There should be an explicit focus on the concept design of next generation defence products and systems in the entire sector. These should be spearheaded by strategic designers, speculative designers, as well as detailed concept designers.

28. There should be an effort to organize and encourage HCD-based tradeshows that showcase the next-generation of human-centric products, systems, and services.

29. Commission trade studies and visioning roadmaps for various aspects of HCD that chart its future in the defence sector in India.

30. Government agencies (DRDOs, Ministry of Defence), in consultation with the forces, should develop a roadmap about how HSI activities will be taken up jointly by various wings of the defence forces for a systems viewpoint towards the inclusion of HSI.

5. Conclusion: Future opportunities

As India is gearing up to become self-reliant in technologies in the defence sector, there is an urgent need to incorporate HCD principles, techniques, methodologies, and practices. Indian defence forces need not only good technology but also good human-centered technology. The emphasis on HCD for defence will provide this pathway. In order to make HCD relevant for the Indian defence sector, there is a need to comprehend a broader understanding of HCD that incorporates design, human factors, and human systems integration. Such a broad conception of HCD will also require a renewed effort from traditional design schools to cater to the unique challenges of Indian Defence at the sectoral level. Further, there is a need to incorporate HCD at various levels of sectoral operations ranging from multi-functional teams to strategic level of government program directorates. In addition, various stakeholders, ranging from end-users to program managers, require an understanding of the value of HCD for the defence forces. This policy brief identified a few major challenges and barriers that stop the inclusion of HCD in the defence sector. Based on these issues, 30 recommendations were provided to integrate HCD-based principles, practices, and insights to support a multi-level sectoral inclusion for Indian defence. The sectoral engagement of HCD will ensure that the dimension of human centricity is integrated into Indian Defence.

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Acknowledgements

Thanks to all the committee members of CII National Committee on Design 2023-24, for comments and suggestions on the report.

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