Office of the Principal Scientific Adviser
to the Government of India

सत्यमेव जयते

INVEST INDIA
NATIONAL INVESTMENT PROMOTION & FACILITATION AGENCY

agnii
IGNITING IDEAS

Enhanced Personnel Performance

Technology Advisory Note

Enhanced Personnel Performance

Technology Advisory Note

March 2023

AGNIi Mission

Office of the Principal Scientific Adviser to the Government of India

Conducted in collaboration with the National Disaster Response Force

Team

Manali Amitav

Vikrant Khazanchi

Rahul Nayar

Deepankar Phalnikar

Anagh Singh

Rishabh Surendran

FOREWORD

India is one of the most severely impacted countries in the Global Climate Risk Index 2021. It faces various disasters across the subcontinent from earthquakes and landslides in the Himalayan North to cyclones and floods across its vast peninsular region and coastline. Emerging technologies and innovations in disaster response are crucial to our role; these can be force-multipliers for our rescuers and the field commanders. As exemplified by "Ops Dost" in Türkiye, NDRF may also be expected to respond to disasters anywhere in the world, that is getting impacted by disasters with increasing frequency and ferocity because of climate change.

In this regard, our partnership with Office of Principal Scientific Adviser to the Government of India, and its AGNIi Mission has been an important and much appreciated source of support and insights. The AGNIi Mission representatives have frequently interacted with NDRF rescuers to understand what we need and have identified start-ups and technologies that can help address these needs. They have conducted field technology showcases with Force battalions to examine how practical and actionable these technology-powered options are in realistic scenarios.

I am pleased to acknowledge this Technology Advisory Note, capturing key aspects of our collaboration. This advisory will help improve the Force's responses as we engage with the wider Indian innovation ecosystem and navigate our path of ever-improving organisational agility and capability with indigenous technology initiatives.

I would like to express my appreciation and gratefulness to the Office of Principal Scientific Adviser and AGNIi Mission for their support and look forward to advancing our partnership and collaboration. I am sure this collaboration can help NDRF create a benchmark of disaster response in the world.

Sh. Atul Karwal, IPS
Director-General, NDRF

Table of Contents

PART A | INTRODUCTION | OBJECTIVE AND METHODS *1*

A.1 Office of PSA | AGNIi Technology Advisory Note 3

A.2 Scaled Institutional Impact: Are TAN and Technologies Applicable Across Forces? 4

A.3 Methodology | Actionable Advice for Scaled Impact: Exemplar Projects 6

PART B | STRATEGIC CONTEXT | PROBLEMS AND CHALLENGES *11*

B.1 Strategic Factors Defining Technology Adoption: Scaled Impact Against a Scaled Challenge 11

B.2 Understanding and Distilling the Pain-points: Operational Scenarios and Functional Requirements 16

PART C | TECHNOLOGY | FEATURES, CAPABILITIES AND STACKS *30*

C.1 Functional Requirements to Building Features: Technology Stack 30

C.2 Block 1: Technical Textiles 30

C.3 Block 2: Exoskeletons 38

C.4 Block 3: Resilient Communications 43

PART D | DEMONSTRATION | FIELD TERRAINS AND CONDITIONS *55*

D.1 Context and Approach 55

D.2 Technical Textile-based Uniforms 58

D.3 Self-Powered Exoskeletons 65

D.4 Satellite Communication and Private Wireless Networks 69

PART E | WAY FORWARD | ASSESSMENT AND ADVISORY REMARKS *77*

E.1 Summary 77

E.2 Assessment and Advisory Matrix 77

PART A | INTRODUCTION | OBJECTIVE AND METHODS

This Technology Advisory Note (TAN) results from a collaborative effort between the Office of the Principal Scientific Adviser to the Government of India's AGNIi Mission, and its partner, the National Disaster Response Force (NDRF).

1. The Note advises and informs administrative action either:

    a. Under the Empowered Technology Group mechanism, chaired by the Principal Scientific Adviser (PSA) and serviced by the Office; advancing the Group Constitution order[1]:

        i. Objective Para 3(i): *Identify the most important challenges before the country across various sectors that can be addressed through suitable and appropriate technologies;*
        ii. Objective Para 3(ii): *Identify key technologies, both legacy and emerging, that are most relevant to the country's needs and challenges;*
        iii. Objective Para 3(iii): *Advise the Government on suitable policies and strategies for effective, secure, and context-sensitive exploitation of latest and appropriate technologies;*
        iv. Objective Para 3 (vii): *Advise the Government on its technology supply and procurement strategy*;
        v. Mandate Section 4.2: *Procurement Support*;

    b. Or: under similar and related mechanisms;

2. To do so, the Note – and the collaborative exercise this captures – advises:

    a. How important challenges the Force identifies – strategic / operational / tactical – can be addressed through Indian technology; captured via Pain-Points, Use-Cases, and Operational Scenarios;

    b. Identifies technologies that are relevant to resolving these challenges; captured via technology Operational Scenarios, Technology Stacks comprising examples of Indian technological innovation, and Field Technology Showcases conducted with partners;

    c. Identifies and assesses how, consequently, the Force can engage and exploit these technologies to engage those challenges, in a manner optimised to context; in the final Technology Assessment section;

    d. Informs – in a manner that is never vendor-specific; with showcased start-ups simply offering indicative examples of existing Indian innovation – administrative action supporting procurement and execution; across the combined Technology Advisory Note;

[1] Cabinet Secretariat Order dated 28 February 2020 F No. Prn.SA/Adv./DCNTG/42/2019 'Constitution of an Empowered Technology Group – reg.'; read with Office Memorandum dated 29 February 2020 No. 1/17/1/2020-Cab 'Preparation / submission of notes for consideration of the Cabinet and Cabinet Committees – Empowered Technology Group - reg.'

Empowered Technology Group Objective	**Technology Advisory Note Section**
Para 3(i): *Identify the most important challenges before the country across various sectors that can be addressed through suitable and appropriate technologies*	Strategic Factors Defining Technology Adoption Pain-Points User Persona Mapping Use-Cases Operational Scenarios
Para 3(ii): *Identify key technologies both legacy and emerging that are most relevant to the country's needs and challenges*	Pain-Points User Persona Mapping Use-Cases Operational Scenarios Technology Stacks Field Technology Showcases
Para 3(iii): *Advise the Government on suitable policies and strategies for effective, secure, and context-sensitive exploitation of latest and appropriate technologies*	Technology Assessment
Advise the Government on its technology supply and procurement strategy	Combined Technology Advisory Note

A.1 Office of PSA | AGNIi Technology Advisory Note

1. This Technology Advisory Note, henceforth TAN, focuses on how **emerging technology and innovation** – capabilities for which exist in **India's innovation ecosystems**, start-up, and laboratory – can **support enhanced performance for Central Forces personnel in environmentally hostile field situations.** This **begins with teams, deployed in disaster situations,** of the National Disaster Response Force (NDRF). This advisory, developed through NDRF's pioneering participation, can apply more widely to infantry across the Central Forces. This innovation includes exoskeleton, technical textile, and advanced communications technologies to enhance rescue capacity of personnel – their survivability, capacity, and coordination.

2. The Office of the Principal Scientific Adviser to the Government of India, in partnership with national government agencies, identifies and **advises** on how Indian emerging technologies (such as artificial intelligence, blockchain technology, nanotechnology, advanced sensing, and others) can be leveraged to help address national priorities. Key among these is disaster response, and the performance of Central Forces personnel in environmentally hostile field situations. The Office's advisory is optimised for relevance, supporting specific decisions; and for execution, providing decision-makers with guidance they can use in the field. This allows Government agencies with a usable basis for drawing on emerging technology and innovation. By shaping scaled Government engagement with Indian innovation, the Office advisory, if executed by agencies concerned, will generate scaled opportunity for Indian start-up and laboratory innovation.

3. The TAN summarises guidance developed in collaboration with the National Disaster Response Force, acting as a Pioneer Agency. This guidance was developed via fieldwork, Technology Operational Scenarios, Technology Capability Stacks, and Field Technology Showcases developed under the direction of NDRF Headquarters (at the Director General, Inspector General, and Deputy Inspector General tier); and the aegis of various Force Battalions (at the Commandant tier).

4. Its generating activities were undertaken in partnership and consultation with NDRF commanders and officers, and leadership tier both at Force and Battalion level: the Note and its advice aims to **support practical, actionable administrative decision-making on technology engagement** and acquisition across Provisioning, Operations, Human Resources / Personnel, and technology-focused Directorates. This, at NDRF as a Pioneer Agency – the example of which may be emulated across State Disaster Response Forces (SDRFs). Aligned to the Government's Aatmanirbhar Bharat priority, the TAN focuses on Indian technological innovation.

5. Equally, the Technology Advisory Note – and the exercises that generate it (technology operational scenarios, stack development, field technology showcases, etc.) – are exercises in **change management**. They seek to support leadership in driving a wider process technology-enabled transformation across their agencies. The analyses and output provide leadership with tools and levers with which to do so.

6. No part of any TAN should be construed as, or be interpreted or derived to generate, support for any individual vendor, start-up, innovator, or private actor of any kind. The TAN features specific technologies – whose innovator start-ups and laboratories volunteered to participate in Field Technology Showcases – merely as examples of broader technological capabilities' existence and readiness within Indian innovation ecosystems, and of how Aatmanirbhar Bharat can be effectively advanced even while supporting key national priorities. At every stage, Government agencies and Forces must follow due process under competent authority in engaging, selecting, procuring, and deploying technology.

A.2 Scaled Institutional Impact: Are TAN and Technologies Applicable Across Forces?

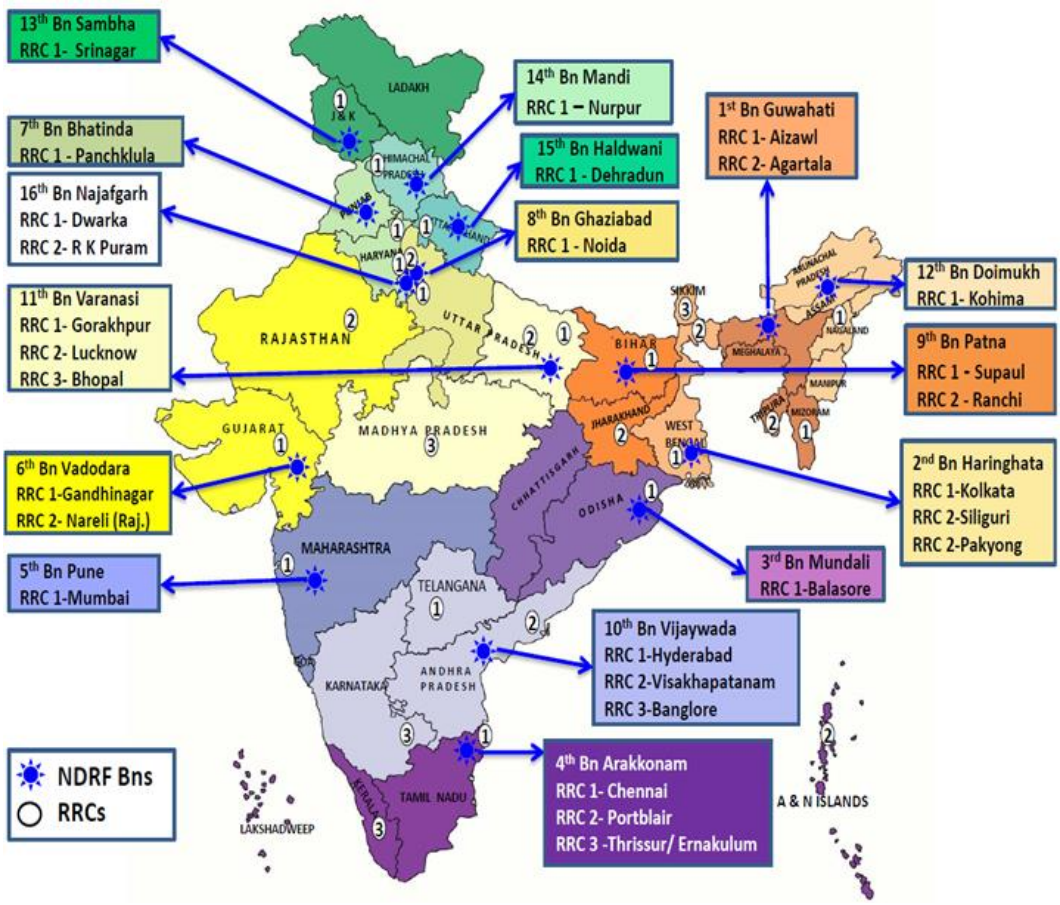


Figure 1: *Map showing NDRF Battalion locations and their respective area of responsibility*[2]

1. The NDRF acts as the national agency for disaster response - comprising of 16 battalions across from the BSF, CISF, CRPF, ITBP, SSB and Assam Rifles. Each battalion has 18 self-contained specialist search and rescue teams of 45 personnel each including engineers, technicians, electricians, dog squads and medical/paramedics. The total strength of each battalion is 1,149. All the 16 battalions have been equipped and trained to respond natural as well as man-made disasters. Battalions are also trained and equipped for response during chemical, biological, radiological, and nuclear (CBRN) emergencies[3].

2. As per Section 3.4.5 of National Policy on Disaster Management 2009, the State Governments are required to raise their own SDRFs for rapid disaster response. Each SDRF is located at strategic locations well connected to transport hubs and rail-heads. SDRFs have missions closely resembling that of the NDRF.

3. The Ministry of Home Affairs (MHA) notes a total of 29 States and Union Territories[4] having established their own SDRFs. This provides a nationwide scaling network, driving wider adoption of the technology capacities

[2] National Disaster Response Force. Ministry of Home Affairs, Government of India. *About Us.* https://www.ndrf.gov.in/about-us
[3] ibid.
[4] National Disaster Management Authority, Government of India. *State Disaster Response Force.* https://ndma.gov.in/Response/SDRF

that AGNIi identifies with the NDRF: with individual State Forces emulating the national tier agency to boost capability. This institutional scaling would be catalysed by organisational mapping between Central and State Forces, and capacity building across tiers. The SDRFs comprise **over 12,168 personnel**.

4. The collaboration between AGNIi and NDRF on technologies for enhanced personnel performance in disaster response therefore addresses a pool of approximately **26,000 personnel.**

5. Crucially: the main focus areas of the TAN – enhancing personnel's ability to survive, operate (including carrying loads), and coordinate in environmentally hostile field situations – applies across multiple Central Forces. This applies to up to six Forces, comprising approximately **8.4 lakh personnel** (please see below).

		BSF			CISF		SSB			
		2,65,277	17,235	94,358	1,63,498	3,24,654	97,790	88,430	65,143	10,000
1	Project 'Enhanced Personnel Performance'	✓	✓		✓	✓	✓	✓	✓	✓
2	Project 'Facilities Defence'	✓		✓	✓	✓	✓	✓	✓	✓
3	Project 'Unmanned Systems for Hostile Environments'	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	Project 'Force Personnel Training'	✓	✓	✓	✓	✓	✓	✓	✓	✓
5	Project 'Border Surveillance and Counter Infiltration'	✓					✓	✓	✓	✓

Figure 2: *AGNIi Exemplar Projects mapped against all MHA Central Forces to indicate scaled impact*

A.3 Methodology | Actionable Advice for Scaled Impact: Exemplar Projects

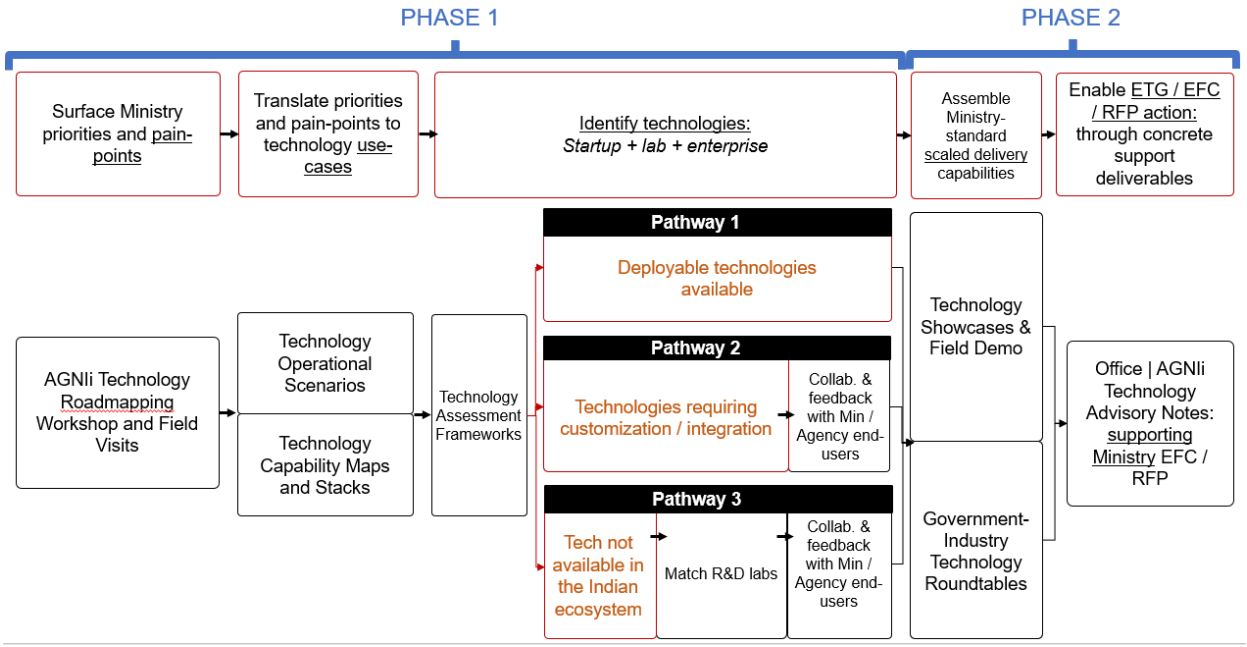


Figure 3: *Office of PSA | AGNIi Workflow*

1. **Practicality: Ensuring Technology Decision-Making Support is Actionable.** To ensure that agency decision-makers receive technology and innovation advice that is **actionable in the field**: the Office's AGNIi Mission, under the Prime Minister's Science Technology and Innovation Advisory Council develops this advice through **Exemplar Projects**, executed in collaboration with a **Pioneer Agency**.

    a. **Exemplar Projects** address pain-points identified by senior Government authorities in that sphere as comprising a **major and scaled national priority.**

    b. **Pioneer Agencies** are select organisations within the Government which:
        i. are mandated to engage these national priorities;
        ii. in doing so, demonstrate a high degree of proactiveness and progressiveness in their engagement with innovation, technology, and new ideas; and
        iii. share these priorities with a wider community of similar institutions – allowing scaled impact against these priorities to be assured by the emulation and adaptation of Pioneer Agencies' examples.

2. **Ensuring Decision-Making Relevance: Technology Operational Scenarios.** AGNIi targets emerging technology innovation to support agency priorities and requirements, as follows:

    a. The Exemplar Project analyses and characterises this pain-point, determining its dimensions and decision-factors:

i. Tactical, relevant to field officers. In the Central Forces, this would apply to tiers up to the rank of Deputy Commandant;
ii. Operational, which senior administrative tiers must resolve. In Central Forces, this would apply to tiers from Commandant to Deputy Inspectors General;
iii. Strategic, affecting leadership-tier decision-making. In Central Forces, this would apply to tiers from Inspector General to Director General.

b. To ensure decision-making relevance: AGNIi executes that analysis and characterisation as follows:
   i. To determine tactical and operational decision-making dimensions: AGNIi team visits to field locations – selected for representing the most challenging circumstances the Pioneer Agency faces – to research and characterise pain-points as they are experienced and determined the ground.
   ii. To determine operational and strategic decision-making dimensions: the AGNIi Mission also consults, via a series of meetings, with Pioneer Agency officers at the Secretary (Central Forces Director General), Additional Secretary (Central Forces Additional Director General), Joint Secretary (Central Forces Inspector General), and Director (Deputy Inspector General) ranks.

3. **Solving Challenges with Technology: The Technology Stack.** The Project then formulates a 'stack' of emerging technologies – within Indian startup and laboratory capability, demonstrated through specific examples – which can engage these challenges.

   a. Technology Stacks integrate innovation across multiple **technologies** – for example, advanced communications, advanced materials;

   b. They position these technologies against operational **capabilities** required – for example, coordinated communications in disaster scenarios;

   c. Where these technologies and capabilities **intersect** – **solutions** are identified – for example, resilient communications (at the intersection of satellite communications and disaster scenarios);

   d. For each of these solutions – **examples of concrete Indian innovation** are identified; in the form of startup or laboratory innovation. This offers the agency clarity that Indian innovation is available, under Aatmanirbhar Bharat objectives, to solve its challenges.
      i. Crucially, these examples (and the wider TAN) do not recommend or endorse any particular vendor;

   e. These technologies and capabilities are framed in terms of how **they work together**, to offer **workable solutions to the broader operational challenge** that the Technology Operational Scenario identifies and characterises.

4. **Demonstrating Workability and Options: Field Technology Showcases.** To demonstrate this innovation's practical potential – actual impact on the ground, for Government decision-makers, against these priorities – the AGNIi team conducts Field Technology Showcases (FTS) in locations representative of those where these priorities are encountered.

   a. Hosted by the Pioneer Agency, startups and laboratories are invited to demonstrate how their innovation resolves these pain-points in the field.

b. The Showcases generate assessments for decision-makers on whether, and to what extent, innovation in its current form can resolve these pain-points.

c. The Exemplar Project consequently seek to represent the microcosm of the sphere they are working in. The Pioneering Agency is one which deals with this 'microcosm' as a part of their regular functioning.

d. Importantly: Field Technology Showcases do not substitute technology evaluations conducted as part of the public tender process. Instead, they seek to help agency officers expand decision-making options in their quest to engage key priorities.

e. **Crucially:** Field Technology Showcases seek to **support the actual adoption** of relevant, effective innovation, by activating five crucial levers of innovation diffusion. First identified by innovation scholar Everett Rogers, in his development of the Diffusion of Innovation curve or Rogers' Curve (Figure 4): these factors, if demonstrated, drive adoption decisions. Each Field Technology Showcase seeks to demonstrate these. This has been elaborated on, for each technology in Part D.

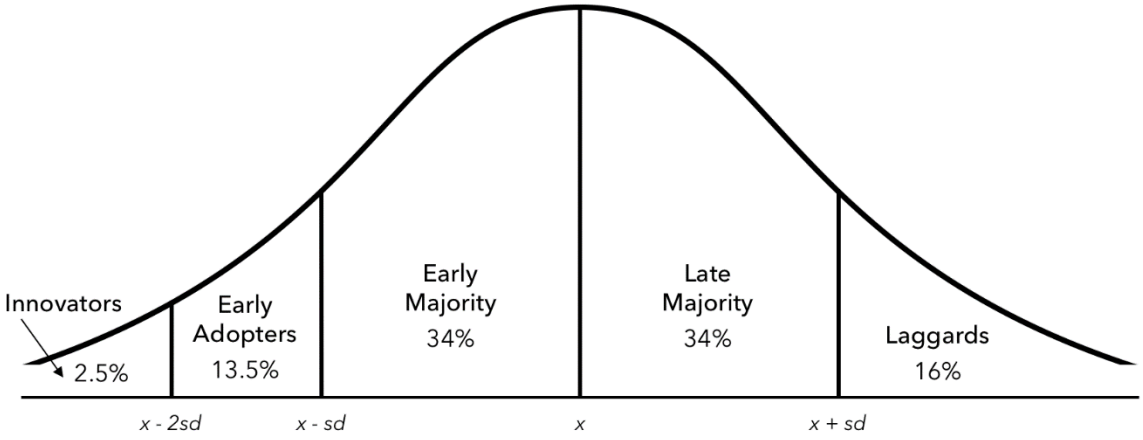


Figure 4: *Relationship between types of adopters classified by innovativeness and their location on the adoption curve*[5]

5. Advice (and supporting analyses) are captured in Technology Advisory Notes: supporting specific administrative action to engage and leverage Indian emerging technology within the Pioneer Agency, and across Government agencies, in fulfilling national priorities at **scale**.

6. Change Management: Supporting Agencies in Transformation through Innovation. The Office of PSA's key objective, in its collaborations with agencies engage Indian emerging technology and innovation in answering national priorities – through the collaborative model outlined above. This embrace of innovation, with Office support, involves institutional change: with agencies upgrading their organisational capabilities through technology. The AGNIi advisory project cycle described above supports this, activating eight change management levers.

[5] Everett M. Rogers, *Diffusions of Innovations,* 5th ed. New York: Free Press, 2003. p.281.

STEP	CHANGE MANAGEMENT LEVER	COLLABORATIVE ACTION	AGNII TECHNOLOGY ADVISORY WORKFLOW PHASE
Step 1	**Establish and identify urgency**	Frontier and Force leadership consultations: Inspector General direction, Deputy Inspector General tier, aligned to priorities / guidance / values set by Director General. - Priorities on enhancing performance of NDRF teams and personnel in rescue operations, as well as defending civilians and Force personnel from violent attacks. - Profile, risk, capabilities required in disaster scenarios Battalion-tier consultations with field-commanders: Commandant, Dy Comdt. tier. At Exemplar Site in the field, representative of rescue risks.	Agency Pain-Point Mapping Workshops / Consultations Field Visits
Step 2	**Form guiding coalition of authority**	Collaboration with Force leadership and field commanders: intersecting operational and tactical interests and urgencies. Develop Technology Operational Scenarios with Force and field commanders: representing that intersection.	Agency Pain-Point Mapping Workshops / Consultations (including in field or field-realistic locations) Technology Operational Scenarios
Step 3	**Collaborate to surface Force / Agency vision**	Develop Technology Operational Scenarios with Force and field commanders (Deputy Inspector General, Battalion Commandants, under HQ guidance): describing baseline scenarios and target end-state. Develop Technology Stacks: reflecting functional requirements generated by Operational Scenarios. Collaborating with Frontier HQ and field implement Field Technology Showcases: demonstrating how Indian innovation (representing Stack elements), in realistic field scenarios, delivers target end-state.	Technology Operational Scenarios Technology Stacks Field Technology Showcases (Virtual Technology Showcases for initial assessments)

Step 4	**Communicate the vision**	Demonstrate Indian innovation providing solutions – and alternatives to conventional decision-making options – in realistic field scenarios. Showcases demonstrated to: -strategic leadership (Director General; Inspector General); -operational command (Deputy Inspector General) and -tactical leadership (Commandant, Deputy Commandant) representing solutions answering interests and imperatives across decision-making tiers.	Field Technology Showcases Field Technology Showcases (Virtual Technology Showcases for initial assessments)
Step 5	**Enable decision-makers to act on that vision**	Evaluation (e.g., via Boards) of Field Technology Showcases: supporting further administrative action. TAN supports scaled action within and across Agencies.	Field Technology Showcases Technology Advisory Notes
Step 6	**Build momentum via successful short-term action**	Specific use-cases driving Technology Operational Scenarios; demonstrated by Field Technology Showcases; advanced iteratively. Support to agile engineering approaches.	Technology Operational Scenarios Technology Stacks Field Technology Showcases
Step 7	**Consolidate improvements for further change**	Feedback delivered from evaluations to Stack innovators (on product feature sets), Forces and AGNIi (on technology functioning vs. Technology Operational Scenarios)	Technology Operational Scenarios Technology Stacks Field Technology Showcases
Step 8	**Support institutionalisation of new approaches**	Supporting administrative action	Technology Advisory Notes

PART B | STRATEGIC CONTEXT | PROBLEMS AND CHALLENGES

B.1 Strategic Factors Defining Technology Adoption: Scaled Impact Against a Scaled Challenge

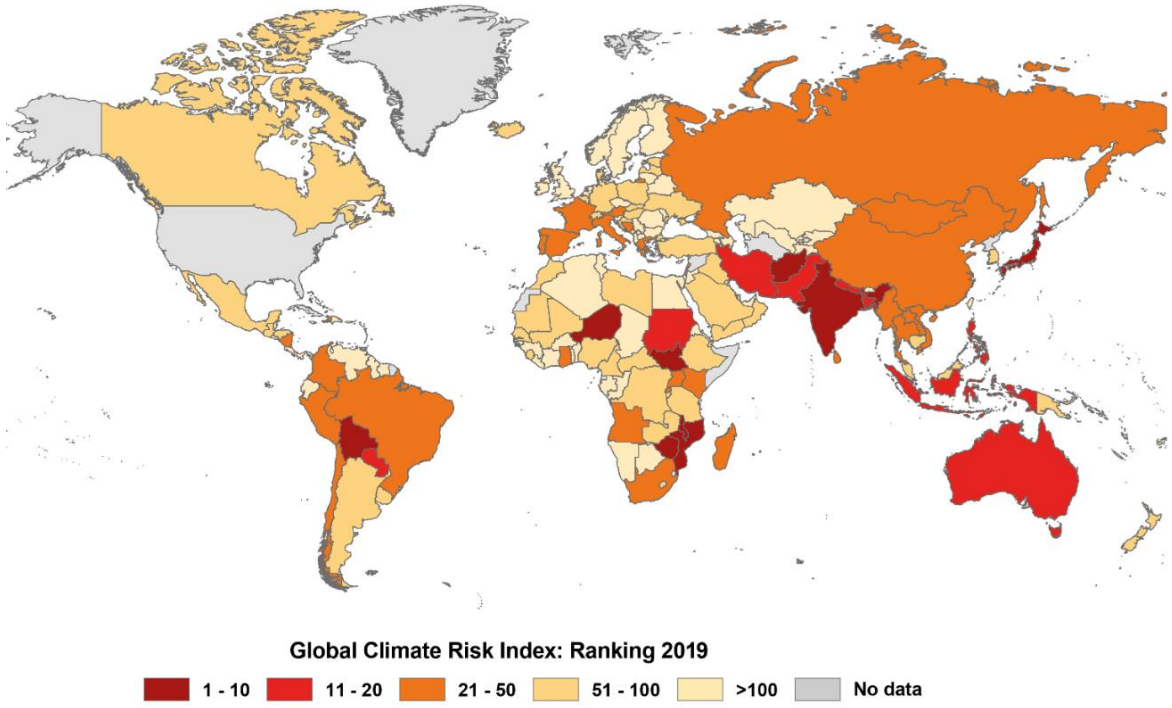


Figure 5: *India was 7th most impacted due to extreme weather events in 2019*[6]

1. This Technology Advisory Note (TAN) outlines how emerging technology and innovation – capabilities of which exist in India – can help enhance the performance of personnel deployed by the NDRF, and SDRF, in field rescue. It also applies to other Central Forces personnel deployed in high pressure situations. Developed in collaboration with the National Disaster Response Force, the TAN engages a nationally scaled challenge.

2. India is one of the most disaster-prone countries in the world[7]. Several factors such as the location and geographic characteristics serve as catalysts for several natural hazards such as floods, cyclones, fire, droughts, landslides, earthquakes, and avalanches. Climate change has been exacerbating these hazards, increasing vulnerabilities of the country[8]. India is the **seventh most impacted country due to extreme events caused by climate change**[9]. The Government of India passed the Disaster Management Act in 2005 to provide an

[6] David Eckstein, Marie-Lena Hutfils and Maik Winges, *'Global Climate Risk Index 2019'*, Germanwatch;
[7] David Eckstein, Vera Kunzel, Laura Schafer, '*Global Climate Risk Index 2021*', Germanwatch;
[8] Mohanty, Abinash and Shreya Wadhawan. 2021, '*Mapping India's Climate Vulnerability: A District-Level Assessment*' New Delhi: Council on Energy, Environment and Water
[9] David Eckstein, Vera Kunzel, Laura Schafer, '*Global Climate Risk Index 2021*', Germanwatch;

overarching framework for the entire disaster management cycle. The National Disaster Management Authority (NDMA) is the apex authority that conceptualises the national policy for disaster management. It is aimed at building a safer, disaster-resilient, proactive, and technology-driven sustainable development strategy. The focus is on fostering a culture of prevention, preparedness, and mitigation.

3. NDRF has **rescued over 1.48 lakh people** and **evacuated more than seven lakh stranded persons** from disaster situations within the country and abroad, including successful rescue operations in Japan (2011), Nepal (2015) and Turkey (2023).[10]

4. The National Disaster Response Force was constituted under the Disaster Management Act, 2005. As per the Act, the general superintendence, direction, and control of the Force shall be vested and exercised by the National Disaster Management Authority and the command and supervision of the Force under the Director-General. At present, NDRF consists of 16 battalions from the BSF, CISF, CRPF, ITBP, SSB and Assam Rifles. Each battalion has 18 self-contained specialist search and rescue teams of 45 personnel each including engineers, technicians, electricians, dog squads and medical/paramedics. The total strength of each battalion is 1,149. All the 15 battalions have been equipped and trained to respond to natural as well as man-made disasters. Battalions are also trained and equipped to respond during chemical, biological, radiological, and nuclear (CBRN) emergencies.

5. The Disaster Management Act, 2005 lays down the institutional framework for a coherent response across the disaster management cycle in India. Further, as a responsible State, India is a signatory to the Sendai Framework for Disaster Risk Reduction. In pursuance of the commitments made therein, India has conceptualised a National Disaster Management Plan (NDMP). The NDMP 2019 illustrated the institutional framework for decision making and coordination. This helps contextualise NDRF's role in the larger context of India's disaster management framework.

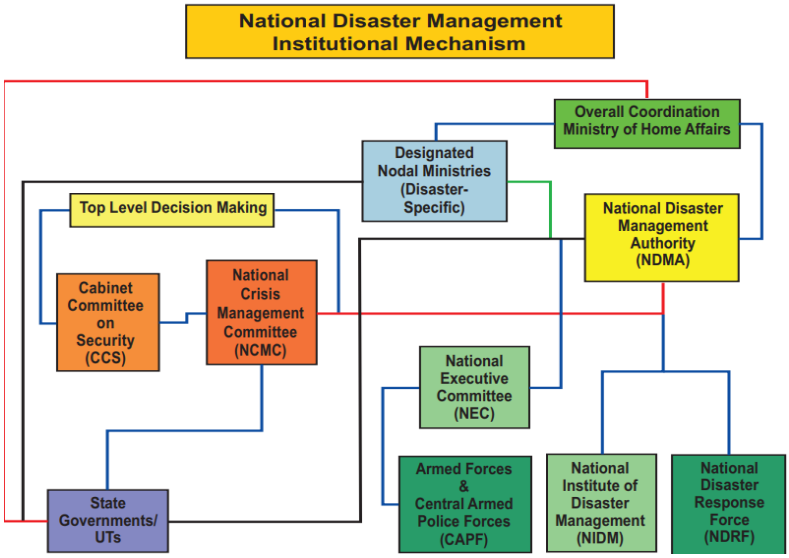


Figure 6: *National Disaster Management Institutional Framework*[11]

[10] Ministry of Home Affairs, Government of India. National Disaster Response Force. *DG's Message.* www.ndrf.gov.in
[11] Source: National Disaster Management Plan 2016

6. The overall superintendence and direction of the NDRF vests with the National Disaster Management Authority (NDMA) as laid down in Disaster Management Act, 2005. NDRF has been constituted as per Chapter-VIII of the Disaster Management Act, 2005 as a specialist response force that can be deployed in a threatening disaster situation or disaster.

    a. As per the Disaster Management Act, the general superintendence, direction and control of the NDRF shall be vested and exercised by the NDMA. The command and supervision of the NDRF shall vest with the Director General appointed by the Government of India. The NDRF has positioned its battalions at different locations as required for effective response.

    b. The NDRF units maintain close liaison with the designated State Governments and are available to them in the event of any serious threatening disaster situation. The NDRF is equipped and trained to respond to situations arising out of natural disasters and CBRN emergencies. Experience in major disasters has shown the need for pre-positioning of some response forces to augment the resources at the State level at crucial locations including some in high altitude regions.

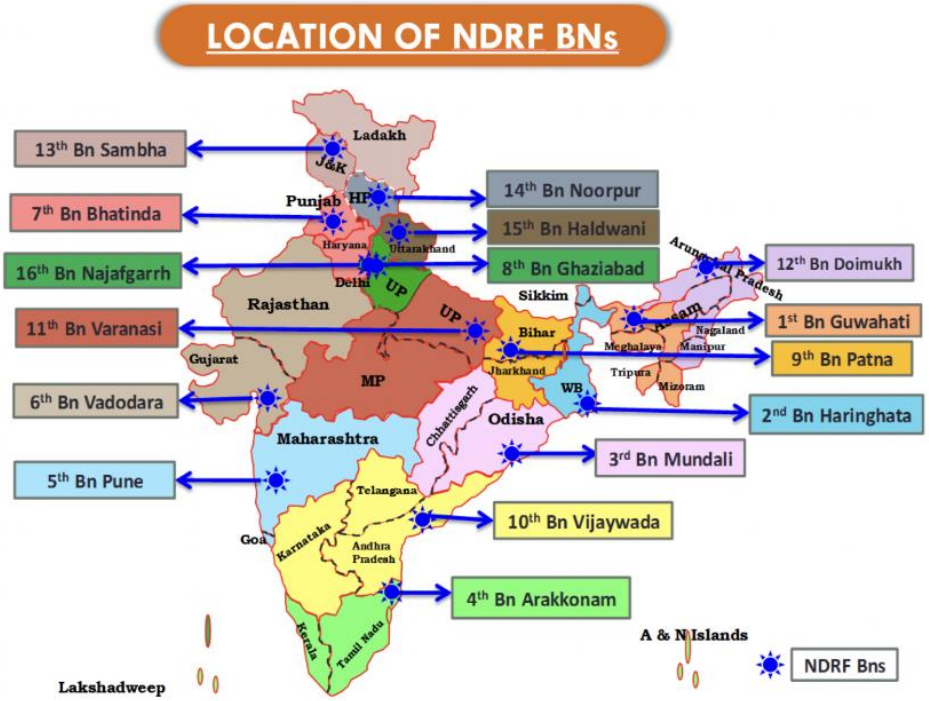


Figure 7: *Map indicating locations of all NDRF Battalions in India*[12]

7. NDRF battalions are located at 16 different locations in the country (Figure 7) based on the vulnerability profile of country. In this context, resources that can enhance the capabilities of the force personnel will be critical. All relevant equipment and technology remain essential to the troops. Enhancing their capabilities presents a critical lever to enhance the performance of the force.

[12] National Disaster Response Force. Ministry of Home Affairs, Government of India. *About Us*. www.ndrf.gov.in/about-us

8. Technology is being deployed for operational as well as strategic directives enabling **risk reduction, mitigation, preparedness, response, and recovery**. It is being deployed throughout the disaster management cycle. The disaster management cycle includes the sum total of activities, programmes and measures which can be taken up before, during and after a disaster to reduce its impact and recovery from loss. The disaster management cycle has been illustrated below.

Figure 8: *Disaster Management Cycle – Mitigation, Preparedness and Response*[13]

9. The mandate of NDRF restricts it to Response and Relief Operations only. As such, the technological interventions must be geared towards enhancing personnel performance in this particular domain.

10. **Strategic Context: High Uncertainty in Field Situations.** A key element in Force responses to disasters and high-pressure field situations is uncertainty. Response personnel are placed in circumstances that cannot be predicted, and which involve:

    a. Extended deployments in post-disaster situations: with high flooding, heat, or humidity; without relief, due to the urgency of life saving rescue;

    b. Time-sensitive, complex operations in hostile environments; characterised by destroyed infrastructure in post-disaster scenarios:
        i. Filled with rubble and debris, blocking access to victims;

[13] Khan, H., Vasilescu, L.G., and Khan, A. (2008). *Disaster Management CYCLE – a theoretical approach*. Management and Marketing Journal, 6, 43-50.

ii. With no functioning communications, limiting the ability of teams to coordinate sophisticated operations.

Year	Type of Disasters	States Affected	Total Fatalities
2021	Flood, Landslide	Maharashtra, Karnataka, Telangana	1824
2020	Cyclone, Flood	West Bengal, Odisha, Andhra Pradesh	98
2019	Flood, Landslide	Karnataka, Maharashtra, Kerala	1692
2018	Flood	Kerala, Karnataka, Tamil Nadu	488
2017	Flood	Assam, West Bengal, Bihar	1456
2016	Heat Wave	Andhra Pradesh, Telangana	2500
2015	Heat Wave	Andhra Pradesh, Telangana	2500
2014	Flood, Landslide	Jammu and Kashmir, Uttarakhand, Himachal Pradesh	2231
2013	Flood, Landslide	Uttarakhand, Himachal Pradesh	570
2012	Flood	Assam, Arunachal Pradesh	431
2011	Cyclone, Flood	Orissa, Andhra Pradesh	310
2010	Flood	Bihar, Uttar Pradesh	548
2009	Flood	Andhra Pradesh, Karnataka	1401
2008	Cyclone	Orissa	221
2007	Flood	Bihar, Uttar Pradesh	1800
2006	Flood	Assam, Bihar	1310
2005	Flood	Maharashtra, Gujarat	1791
2004	Tsunami	Andaman and Nicobar Islands, Tamil Nadu, Kerala	16423
2003	Flood, Landslide	Himachal Pradesh, Jammu and Kashmir	1822
2002	Flood	Assam, Bihar	764

Figure 9: *Data for most major disasters affected states and respective fatality count for the last 20 years*[14]

11. **Technology Stack Design Imperative: Individual Performance Enhancement in Environmentally Hostile Situations.** Post-disaster rescue is performed by individual personnel – who form the tip of the spear in any operation. It is personnel who will remove rubble, coordinate support, and keep functioning continuously

[14] National Disaster Management Authority, Centre for Research of Epidemiology of Disasters

in time-contingent situations. This has **implications for technology use-case definitions** and **shapes the Technology Stack**.

Strategic Factor	**Functional Implication**	**Technological Response: Consequences for Technology Stack Composition**
Extended, continuous personnel functioning in time-contingent situations. Destroyed infrastructure environments	Boosted performance for individual constables	Human factor: - Enhanced endurance - Enhanced load-bearing capacity - Resilient communications for operational coordination

B.2 Understanding and Distilling the Pain-points: Operational Scenarios and Functional Requirements

1. A disaster is a hazard occurring over a short or long period of time that causes widespread human, material, economic or environmental loss which exceeds the ability of the affected community or society to cope using its own resources. They may broadly be classified as either man-made, such as industrial disaster, or natural, such as earthquakes, and floods. Disasters create emergency situations and cause physical and social disorder. In these emergency situations, food, water, shelter, protection, and medical help are needed, and the effort needed to provide these basic services to the victims must be coordinated quickly via a reliable communication network. Disaster relief operations typically involves a series of steps including establishment of communication infrastructure, performing search and rescue operations, and providing any needed first aid services.

2. Rescue workers strive, after disasters, to help victims and restrict damage, often in dangerous circumstances. Search and Rescue Teams who rush to help victims and secure the area to prevent further casualties often face dangerous and demanding tasks that involve the risk of possibly fatal injury. In certain floodwater rescue operations, rescuers may need to get in deep waters to lead victims to safety and often extensive perform rescue and relief activities. They also need to navigate debris from collapse of high-rise structures, landslides etc. NDRF has also participated in bilateral exercises and international rescue efforts that require the force to carry heavy equipment to the aircraft. These situations present **multiple stressors for the body**.

3. Search and Rescue operations under high temperature (Fire), wet and disease prone areas (Floods), debris prone regions (Earthquake) extract a psychological and physical toll through consistent discomfort, vulnerability to communicable diseases, pruning due to sustained exposure to water. This impacts the efficiency of the force personnel. A typical operation of the NDRF, done through Search and Rescue teams roughly comprises of the following:

a. **Reaching the disaster struck location**: This involves loading and unloading heavy equipment, clearing the roads of debris, trees to make way for the larger team.

b. **Search and Rescue:** The team needs to cut through concrete, clear debris, move quickly up and down buildings.

c. **Distributing relief materials:** A major role of the teams is distributing relief materials to the victims.

4. **Personnel Human Factor Considerations: Environment Suits.** NDRF personnel are expected to operate under harsh environmental conditions and distress. In terms of their scope of work, NDRF is positioned as the specialist responder in the event of any disaster- natural or man-made. Their work not only entails rescue operations at high altitudes in the Himalayas, but also involves floodwater rescue in Kerala, spanning the gamut of national geographies, topography, and temperatures. During a disaster response mission, they are faced with the most trying circumstances. Additional input in terms of internal and external stimuli can support and augment their overall capabilities.

    a. In such a scenario, the worker's wear should not pose a hindrance to his/her capabilities. It should be completely integrated into their physique and additionally support and enhance their capabilities.

    b. Essentially, it should blend in with their technological aids in the most functional manner. A detailed analysis of the existing uniform of NDRF was carried out and following points were noted:
        i. The current NDRF apparel does not support high-tech functional aspects such as water-resistance and enhanced breathability.
        ii. The core material/textile used in the uniform are not adequate for moisture management and comfortability.
        iii. Existing NDRF uniforms are plain viscose/polyester fabric which is uncomfortable during summers and low on color fastness.
        iv. A global comparison shows that international uniforms are active wear yet formal.

5. **Personnel Human Factor Considerations: Debris Clearing.** NDRF personnel are expected to operate under harsh environmental conditions and distress.

    a. In post-disaster scenarios
        i. Debris removal
        ii. Clearing pathways for the NDRF personnel
        iii. Reducing fatigue, prolonging operational strength
        iv. Heavy equipment loading/unloading

    b. This creates a requirement for:
        i. Reduction in injuries caused due to heavy stress on musculoskeletal system,
        ii. Enhancement in strength to reduce fatigue caused by strenuous and long duration operations;

6. Keeping the above challenges and considerations in mind, Technical Textiles present a low-cost, high-impact way of adequately dealing with such stressors by providing anti-microbial properties, higher resistance to heat and water resistance.

7. Additionally, Exoskeletons present an efficient and augmentative way to assist the responders in load-bearing activities like moving equipment, debris removal etc. thereby reducing personnel fatigue and chances of injuries to the musculoskeletal system.

Figure 10: *NDRF personnel during a rescue operation in Guwahati.*[15]

The table below gives a succinct brief on how the pain points translate to a functional requirement of the technology –

Pain Point	Operational Scenario	Use Case	Functional Requirement
Office and combat uniform do not provide the capabilities required for a disaster response force	1. The current NDRF apparel does not support high-tech properties such as water-resistance and enhanced breathability. 2. The core material/textile used in the uniform are not adequate for moisture management and comfortability. 3. Existing NDRF uniforms are plain viscose/polyester fabric which is uncomfortable during summers and low on colour fastness.	Integrating technical textiles in the current NDRF uniform to make disaster rescue work safer and more efficient thereby improving the chances of success and reducing the risks faced by rescue workers.	Following features can be incorporated for upgrading the existing uniform of NDRF Fresh Uniform (Silver-based Antimicrobial and Odor Control): ▪ Breathable fabric ▪ Antimicrobial properties ▪ Body odour resistant Water Repellent Uniform: ▪ Promotes a soft hand and preserves perfect breathability ▪ High abrasion resistance ▪ Air–dry capability
Back injury and fatigue due to consistently	1. Rescue operations involving debris clearance	Ability to reduce load on the musculoskeletal system by	The exoskeleton should enable force personnel to lift heavier loads than would be possible for the individual, reduce fatigue by reducing effort

[15] Source: Press Trust of India.

Pain Point	Operational Scenario	Use Case	Functional Requirement
high load bearing operations	2. Clearing pathways for NDRF vehicles, blocked by trees and boulders 3. Heavy equipment loading/unloading	mechanically lifting load or distribution of load through hinge mechanism	required, prevent injuries by preventing overloading of musculoskeletal system and sudden jerky motions.

8. **Personnel and Operational Coordination: Communications.** NDRF Standard Operating Procedure (SOPs) on Effective Coordination and Cooperation during Disaster Response, based on recommendations of International Search and Rescue Advisory Group, requires the Force to set up On Site Operations Coordination Centre to be a link between multiple responders and provide for coordinating and facilitating activities of relief efforts at a disaster site, where coordination is critical to rescue efforts. AGNIi Mission seeks to advise NDRF regarding emerging technologies, keeping in mind their existing SOPs to ensure a seamless integration in the Force operations.

    a. **Coordination for Sophisticated Operations in Uncertain Environments.** Coordination in humanitarian response to disasters is not merely a specific set of actions, but rather an approach to emergency response that attempts to maximize its benefits and minimize inefficiencies. It involves multiple stakeholders. Such coordination of emergency response is challenging as it involves factoring in exigencies typical of an emergency situation such as great uncertainty, sudden and unexpected events, risk of mass casualty, high time pressure and urgency and severe resource shortage, large scale damage and disruption of critical infrastructure. This is complicated by factors such as infrastructure damage, multi authority and massive personal involvement and demand for timely information.

    b. **Communications for Coordination.** Coordination under such arduous circumstances requires effective and resilient communications. Resilience of a communication network is its ability to maintain the same level of functionality in the face of internal changes and external disturbances because of large-scale natural disasters and corresponding failures, weather-based disruptions, technology-related disasters, and malicious human activities.
        i. The disaster struck area, is subject to severe damage in communication infrastructure (network towers, generators, cables) as well as long-term disruption in power supply (substations, transformers, distribution lines). In cases where physical damage hasn't occurred, there is severe congestion in the network due to higher than usual user demand.
        ii. Search and Rescue teams from NDRF need to:
            1) Coordinate among themselves (teams) during the response and recovery stages for effective as well as timely rescue/evacuation, and
            2) Communicate with local relief workers and local governments to coordinate logistics and relief resources.
            3) While the latter is achieved by Satellite phones and QDAs (Quick Deployable Antennas), intra-team coordination is carried out via traditional portable full-duplex two-way radio sets operating on VHF or UHF radio waves.
            4) However, the current equipment, the two-way radio sets are limited by bandwidth. They are unable to transmit at higher data rates and different data formats (video, photo) in addition to not being able to support simultaneous bidirectional communication. Further, off-the-shelf based satellite communication, currently done on a per use basis, is extremely cost-intensive.
            5) These aspects, data rates and costing can be optimized with emerging technologies.

Figure 11: *Disruption in Communication lines due to Cyclone Amphan, 2020*[16]

iii. Based on the above pain-point description, it can be ascertained that a secure, portable, robust, easy-to-operate and minimal setup-based communication technology is deemed fit for the NDRF which can -
    1) be used in harsh and difficult terrains lacking line-of-sight,
    2) work in dynamic operational conditions requiring first responder teams to mobilize quickly,
    3) possess high standards of ruggedness, ingress protection and weather resistance, which shall be used for intra-team coordination and critical information transfer via audio and video messages during live disaster response and recovery operations.

c. **Sample Operational Scenario Case: Kerala 2018.** In 2018, Kerala received rainfall more than 42% of the normal average. This led to the worst floods the state has suffered since 1924. It triggered nearly 341 landslides from 10 districts, release of excess water from 37 dams. This cumulative disaster impacted around 1259 villages, spread across 14 districts. About 5.4 million people were affected, 1.4 displaced and there were 433 casualties[17].
    i. Due to the sheer scale of the visit, the Relief and Rescue operations had to be scaled accordingly. The details of the manpower deployed to comprehensively assist is given below.

[16] The Hindu. *Bengal pegs cyclone Amphan damage at ₹1.02 lakh crore*. June 07, 2020.https://www.thehindu.com/news/national/other-states/bengal-pegs-cyclone-amphan-damage-at-102-lakh-crore/article31771039.ece
[17] Kerala -Post Disaster Needs Assessment, Floods and Landslides. August 2018

ii. The State estimated its recovery needs to be around USD 3 Billion. The floods led to extensive damage to critical infrastructure, both communications and infrastructure.

Figure 12: *A total of fifty-five teams were deployed by the NDRF responders during 2018 Kerala Floods*[18]

iii. Further, based on interactions with NDRF Officers, the case study brings out the following:
   1) The criticality of having independent communications infrastructure
   2) Importance of interoperability to coordinate Search and Rescue operations within NDRF and with other forces
   3) Scalability and Mobility due to the sheer scale of the force's operations

iv. The communication needs, based on such operational scenarios are the following:
   1) **Self-Organization**- It should be simple and quick to deploy, with little human intervention.
   2) **Autonomous Functioning**- As much as possible, be independent of any other system, including wireless or mobile operator networks and power supply networks. An aspect of this is power efficiency that will enhance usage.
   3) **Reliability**- It should be able to maintain a high level of service availability to ensure rescue teams are not stranded and is able to establish a Common Operating Picture for the responders through timely exchange of information.
   4) **Interoperability and Scalability**- Provide a common platform between various organizations involved in disaster assessment, recovery, and reconstruction. It should also be able to support a large number of users, high traffic load levels without significantly impacting performance.

[18] Sumit Kumar Singh. *Kerala Floods: NDRF deploys 18 teams as death toll rises*. DNA India. 17 August 2018. https://www.dnaindia.com/india/report-kerala-floods-ndrf-deploys-18-teams-as-death-toll-rises-2650831

5) **Security**- Emergency networks exchange sensitive and critical information. NDRF should be able to define access rights for users and trust encryption of the network to ensure confidence in the system.

d. The current equipment set, being used by NDRF, as per their Flood Disaster Rescue SOP are as follows:

D.	COMMUNICATION EQUIPMENTS	
1.	INMARSAT	01 No (With Assys)
2.	TX/ RX HF 15 WATT	01 No (With Assys)
3.	UHF/VHF - 20 W	01 No (With Assys)
4.	H/HELD RADIO Set 1-4 W	13 Nos (With Assys)
5.	NIMH BTYS	26 Nos
6.	NIMH BTY CHARGER	06 Nos
7.	SECY BTYS 12 V	04 Nos
8.	MAIN BTY CHARGER	01 No
9.	PORTABLE GEN SET	01No (With sufficient POL)
10.	TUBULAR MAST 36 FT	01No
11.	ELECTRIC EXT. BOARD	01 No
12.	QDA Set	01 No

Figure 13: *Communication equipment list and quantity for a Flood Water Rescue team*[19]

e. Based on a consultation that the AGNIi Mission held with the Deputy Commandant (Communications) at the NDRF HQ, the below details on the existing communication equipment of NDRF were ascertained:

#	Type	Equipment	Numbers Possessed	Current capabilities	Limitations
1	Satellite Communication	QDA	97, soon to be increased to around 300	▪ It comes with a MODEM, laptop, VoIP Phone providing speeds of 2-3 Mbps; ▪ Ease of transport	▪ It needs a flat ground for deployment, which is often unavailable during disasters; ▪ Ku band faces signal attenuation, especially in cyclonic conditions; ▪ Increase in number of QDA's will lead to congestion; ▪ 20 minutes setup time

[19] NDRF Flood Water Rescue (FWR) Standard Operating Procedures. https://ndrf.gov.in/sites/default/files/FLOOD.pdf.

#	Type	Equipment	Numbers Possessed	Current capabilities	Limitations
		Inmarsat-ISAT2	-	▪ Provides reliable satellite communication	▪ Private service, availed on subscription basis entailing hefty recurring expenditure
		BGAN	-	▪ Connects a regular cell phone, through Wi-Fi to BGAN, enabling satellite communication	▪ Recurring expenditure
2	Radio Based Communications	HF-VHF Radio sets	-	▪ Provides inter-team communication ▪ Connects base station of radio set to QDA, enabling satellite communication	▪ Low data rates

f. **Sample Operational Scenario Case: Assam.** There has been a flood in Assam, impacting around 3,000 villages and 2 million people. NDRF has been deployed for search and rescue operations across the state. The Force finds that it needs to deploy many Search and Rescue teams, coordinate with other agencies such as the SDRF, local police amongst others. To complicate the situation further, the Teams face a flooded area, where the communication infrastructure has been down. Due to this, the Teams must deploy their own communication equipment.

i. **With Conventional Technology.** The current equipment NDRF uses are Quick Deployment Antenna (QDA) and satellite phones for establishing intra-team communications and between the Team and Force HQ.

1) The QDA requires 20 minutes to deploy. The team finds that they are unable to find a location with stable ground as flat locations are either inundated or unstable. The team is losing precious time in finding an optimum locale. The Force finds that without adequate, resilient communications, it is unable to coordinate its deployment of personnel, equipment necessary for flood water rescue and relief material.
2) While the QDA is used for intra-team communication, satellite phones are deployed for communicating where this is not possible and for connecting with Force HQ. Due to climate change, disasters today are frequent, of a higher magnitude and simultaneously impact the country. The Search and Rescue Teams find that all these conditions impact their operations. As the Force is deployed at multiple locations, the requirement for satellite phones has increased. This is leading to congestion in the

network as the band allocated to the Force has remained constant. Purchasing more bandwidth is exorbitantly expensive, and the force finds that this money can be utilized for other purposes.

3) This is impacting the operational efficiency of the force. While ultimately, the QDA is deployed and sat phones are used, precious time has been lost. Further, communication is limited to voice communication. The personnel must be equipped with Body cameras to enable video communication. While individually the issues are not many, cumulatively the errors contribute to operationally significant, albeit avoidable, delays.

ii. **With Emerging Technology.** A similar scenario can unfold differently when the Force is equipped with emerging technology that accounts for such difficulties the Force faces. Network in a Box is an example of equipment that is ready to deploy, requiring minimal time for set up, and providing voice as well as video communication.

1) On deployment, the Force finds that it may not need a long time to deploy its equipment, it is able to turn the equipment on with minimal effort, and the Box is not directional thus removing the need for finding stable ground. Further, the Network in a Box can connect with existing telecom infrastructure creating a smooth communication interface between the Team and Force HQ.
2) Higher spectrum due to the 4G band obviates the possibility of both congestion due to multiple users and attenuation due to bad weather.
3) The Force finds that the new equipment is easy to use, requiring minimal training. The use of regular cell phones for communication creates a sense of familiarity amongst the force.
4) These benefits cascade into a significant capability enhancement for the Force. It saves time in setting up communication, eases coordination within the teams and with external stakeholders.

iii. The table below gives a succinct brief on how the pain points translate to a functional requirement of the technology –

#	Pain Point	Operational Scenario	Use Case	Functional Requirements
1	Satellite phones are exorbitantly expensive; reliance on foreign firms for critical needs is undesirable	Force uses Inmarsat ISAT2 and BGAN for satellite communication. It is a private service, availed on subscription basis entailing hefty expenditure;	Communication equipment should be reliable and low cost: This may be achieved through high capital expenditure and low recurring expenditure;	**Sat-Phone:** Low attenuation even in rough weather conditions, adequate data rates to enable uninterrupted audio communication, ease of connectivity (regardless of Bluetooth and wired);

#	Pain Point	Operational Scenario	Use Case	Functional Requirements
2	Communication infrastructure is bulky to carry; multiple equipment required to establish comms and transfer information	QDA operations require multiple equipment (MODEM, VoIP Phone); current Ku band faces signal attenuation, especially during cyclonic conditions; expected increase in QDA from 97 to 300 will lead to congestion as the band purchased by NDRF is the same;		**Network in a Box:** Range be long enough to cover multiple Search and Rescue teams; Low time to establish communication infrastructure; lower signal attenuation than Ku band communication, adequate capacity to avoid congestion;
3	Low data rates	High Frequency-Very High Frequency radio sets used provide low data rates.		**Network in a Box:** support audio and video modes of operation.

9. **User Persona Mapping**

a. User persona mapping refers to the process of collating and segmenting information about potential decision makers[20] and technology adopters. The key objective of the process is to create archetypes of potential technology adopters and decision makers pertaining to procurement and financing. The creation of decision maker and technology adopter archetypes helps in ensuring that the process of technology scouting is precise. This feeds into the larger goal of ensuring technology adoption by bringing the technology that solves the user problem most effectively. This section (tables below) presents details of user persona mapping of the Pioneer Agency as well as the decision makers and potential adopters for each of the layers in the enhanced personnel performance technology stack.

#	Decision-Making Tier	Deputy Inspector General (Ops) and Deputy Inspector General (Prov)	Commandant/2IC (Commanding Officer of the Battalion)	Assistant Commandant/ Inspector (Team Commander)
1	**Role and Key Priorities**	NDRF is a small force dedicated towards disaster response across the country. DIG's in-charge of the vertical at	The Commandant of the battalion is the main officer in-charge of the unit having 18 self-contained specialist search and rescue teams of 49 personnel each including	The Team Commander leads the team of 49 which is self-sustaining in nature with support from canine partners as well. He / She is also in-

[20] Please note that in certain scenarios the decision makers and adopters of technology can be different

		the HQs are required to define and design the strategy along with coordination amongst the various units.	engineers, technicians, electricians, dog squads and medical/paramedics. The total strength of each battalion is 1,149.	charge of community awareness programmes to improve disasters preparedness, Imparting training regarding life saving methods like Medical first Responder, Rope Rescue Technics Chemical Biological Radiological and Nuclear Disaster Response.
2	**Background**	DIG (Ops) is in-charge of the operational deployment along with the strategy to be implemented on ground of the complete 16 battalions of the force. DIG (Prov) is in-charge of procurement of Arms, Ammunition, Vehicles, Clothing, Equipment, Furniture, and other Miscellaneous Stores. In addition to the provisioning of the stores his Branch also passes instructions and lays down policies regarding scales, transfer, allocation, maintenance, disposal, and other allied matters pertaining to stores from time to time. All issues relating to Rations are also the responsibility of the Provisioning Branch.	• CO is the nodal point for almost everything inside the battalion including internal economy, efficiency, and efficacy of the battalion. • Prepare battalion for the mission • Provide vision and guidance for organization Mentor, Coach and train subordinate Company Commanders and Staff Officers • Maintain a high level of Operational Readiness within the Battalion • Provide tough, realistic training • Enforce NDRF Standards on the entire organization • Maintain good order and high morale in their organization • Develop subordinates for positions of increased responsibility	Leads the tactical insertion and implementation of the strategy formulated to respond to a particular disaster. Is in-charge of activation and mobilization of the team at the first call and establishment of Integrated Command Post at the site.
3	**Attitudes and Interests**	DIGs value scaled up technologies which can be used across Battalions. Their interest is in reducing the risks associated with their teams deployed for Collapsed Search and Structure Rescue, FWR and CBRN operations.	Commandant views the technology from user perspective completely with securing the objectives of the various missions being undertaken by his unit. All the battalions have been equipped and trained to respond to natural as well as man-made disasters. He is in-charge of the tactical training and equipment for response	His/her interests are the safe and quick response to the incident while simultaneously following orders from the hierarchy above him/her. Interest lies in the cross section of speed and innovation whether process or product to improve response and create a sense of calm at the disaster site.

		Enhancing the personnel performance while ensuring their safety is the priority along with getting superior ground level intelligence.	during chemical, biological, radiological, and nuclear (CBRN) emergencies as well.	
4	**Behavior and Decision Triggers**	Deployment of the technologies ought to be scalable, MRO is the focus, cost effective, easy to integrate, use modifiable and available	Technology insertion is based on user friendliness, supportability, and reliability.	Views Technology as an aid and force multiplier for his self-sustaining unit. Also, in terms of user friendliness and comfort is critical for the team at the tactical level. Training is another aspect looked at.
5	**Functional Requirements from Technology (Communication)**	DIG (Ops) - Real-time monitoring of Disaster situation and resolving dynamic requirements arising in team deployment and inter-agency coordination DIG (Prov) – Real-time monitoring of Disaster situation and understanding equipment utilization and requirements	Comdt./2IC – Smooth liaison and interfacing with State govt. and district authorities, State Disaster Response Forces, and local relief workers	Team Commander/ Search and Rescue Team (SAR) - Ease in usage and mobility of equipment to disaster site, enabling faster turnaround. Robust, reliable, uninterrupted, two-way communication with other responders in SAR team as well as different deployed teams
6	**Functional Requirements from Technology (Technical Textiles)**	DIG (Ops and Prov) – Field uniform must increase the overall operational and field effectiveness of the force	Comdt./2IC – Easy to carry and equip personnel in team, must minimize fatigue and vulnerabilities for SAR team, reduce injuries/infections to responders during disasters, enhance comfort levels	Team Commander/ SAR Team – Ease in wear, sustained comfort levels for long hours of usage, minimal harm/ingress during fire/water -based rescue, adequate temperature, and humidity control

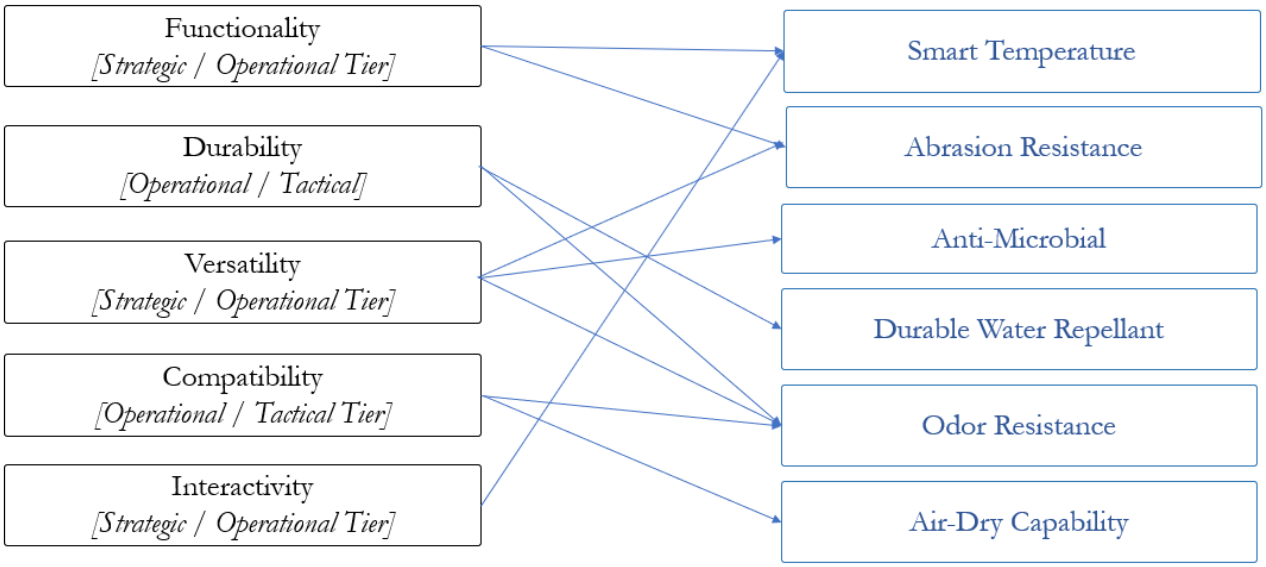
7	**Functional Requirements from Technology (Exoskeleton)**	DIG (Ops and Prov) – Exoskeleton must be a force multiplier for all Search and Rescue team personnel and avoid injuries	Comdt./2IC – Team must be able to split and maximize usage of exoskeletons in a Battalion for load bearing, debris removal and other difficult tasks	Team Commander/SAR Team – Ease in equipping, comfortable fit and wear, reduction in perceived weight/load, fasten operation time

10. **Need-Feature Mapping**

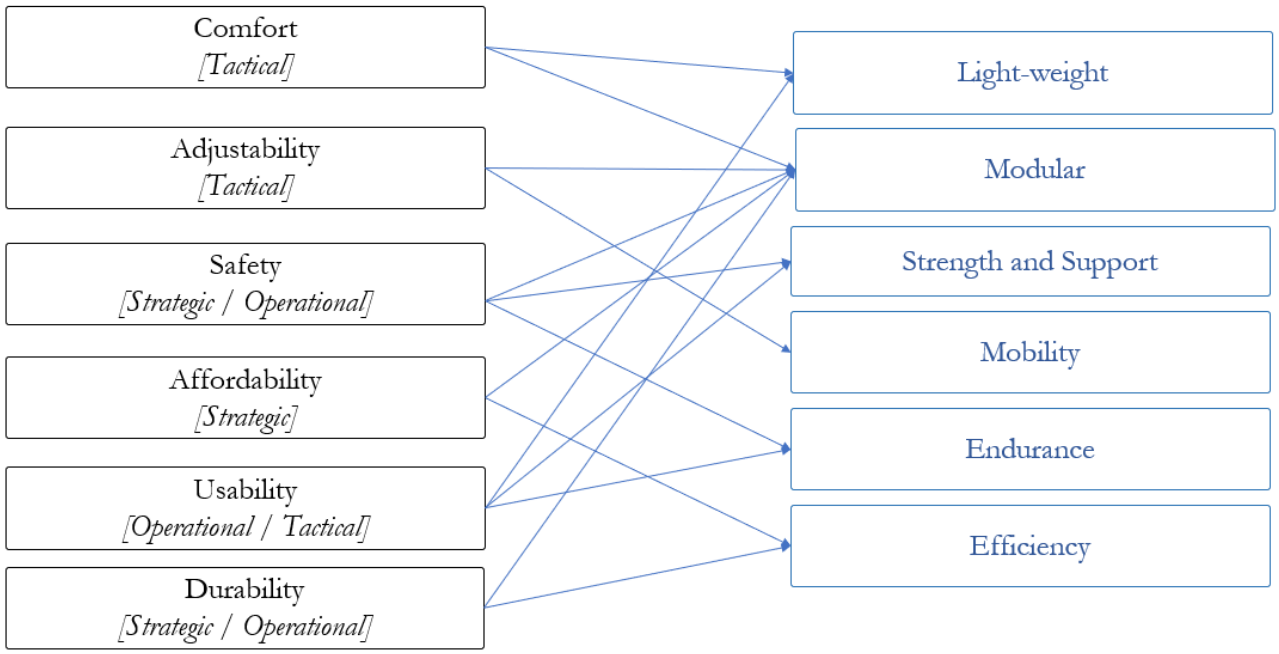
a. The pain-points and operational scenarios for enhanced personnel performance were surfaced via past disasters, focused group discussions and key interactions with relevant stakeholders (all tiers of the NDRF). Subsequently, the pain-points and operational scenarios were translated into technology functional requirements, which were utilised for scouting relevant innovators.

b. The figure below maps the pain-points and needs of end adopters with relevant technology use cases.

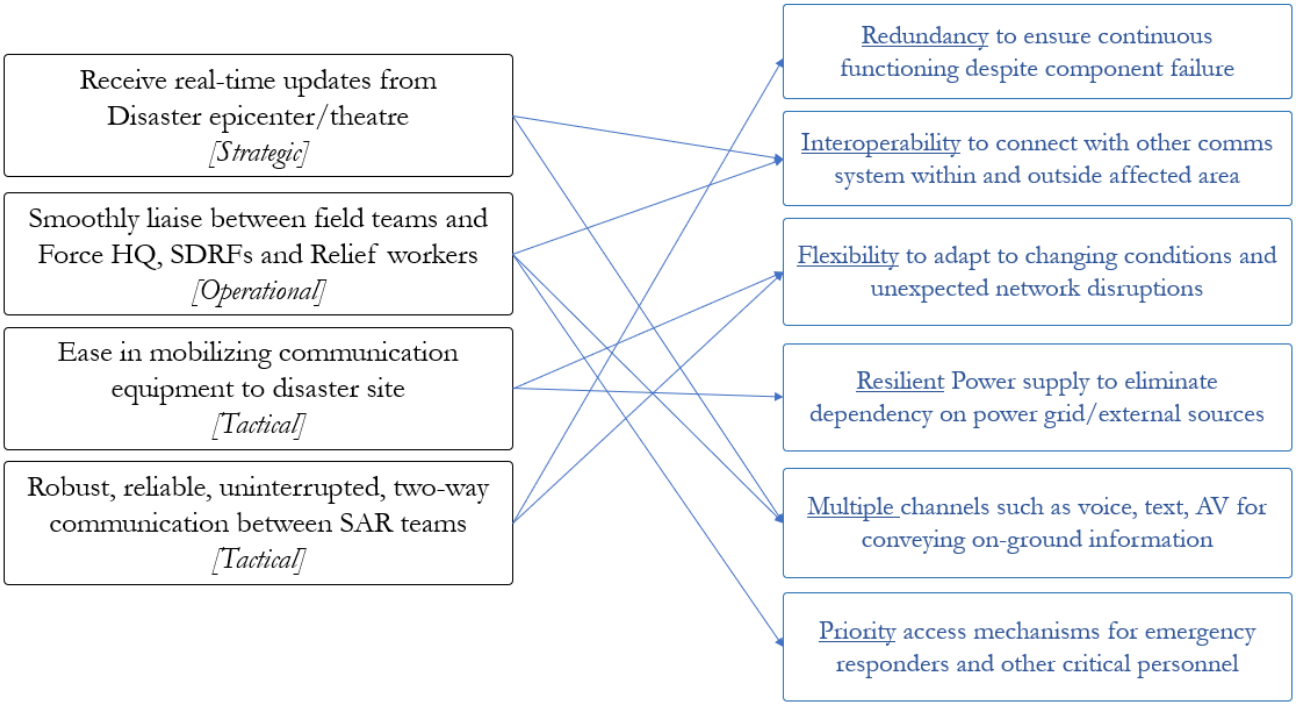
Technical Textiles



Exoskeletons



Resilient Communications



PART C | TECHNOLOGY | FEATURES, CAPABILITIES AND STACKS

C.1 Functional Requirements to Building Features: Technology Stack

1. Based on the functional requirements derived from the pain-points and operational scenarios, key technologies, subsystems and technical components are identified and are mapped against the functionality as well as stage of function to form what is called, the **Technology Stack**.

2. The three vital elements to a disaster responder's functional performance requirement can be mapped to the appropriate technological capability, as below.

Functional Performance Requirement	Technological Capability
Coordination	Resilient communication, rapidly deployable in post-disaster zones where all backhaul capabilities are destroyed Providing communication up to an operational range of 10km
Functioning	Exoskeleton allowing NDRF responders to double the current load carrying capacity (exemplified by the current 25kg pack)
Endurance	Technical Textiles capable of allowing responders in damp, hygiene-stressed, hostile environments for extended time periods

C.2 Block 1: Technical Textiles

1. Technical textiles are fabrics that are designed for specific purposes, such as providing protection, insulation, or filtration. They are typically made from advanced materials and are engineered to perform specific functions. Technical textiles are designed with specific functions and properties to provide performance advantages over conventional textiles. The way a technical textile works depends on its intended function and the specific materials and manufacturing processes used to create it. However, there are some general principles that apply to many types of technical textiles:

    a. First, technical textiles are typically made from advanced materials, such as high-performance fibres or engineered fabrics, that have specific physical, chemical, or biological properties. These materials may be designed to provide properties such as strength, durability, flexibility, or heat resistance, depending on the intended application of the textile.

    b. Second, technical textiles are often engineered using specialized manufacturing processes that allow for precise control of the material properties and characteristics. For example, technical textiles may be created using advanced weaving or knitting techniques, chemical treatments, or coating processes that modify the surface of the textile.

c. Finally, technical textiles work by interacting with their environment in specific ways. For example, a technical textile designed for water resistance may have a specialized coating that repels water, preventing it from penetrating the fabric. A technical textile designed for heat resistance may be made from a material that can withstand high temperatures without degrading or melting. Overall, the key to the function of a technical textile is its specialized design and manufacturing processes, which allow it to provide superior performance in specific applications.

2. Advanced materials used in technical textiles:

    a. **Aramid fibres.** Aramid fibres, such as Kevlar and Nomex, are high-performance synthetic fibres that offer excellent strength, durability, and resistance to heat and abrasion. They are often used in protective textiles, such as body armour or flame-resistant clothing.

    b. **Carbon fibres.** Carbon fibres are lightweight, strong, and have excellent stiffness properties. They are often used in technical textiles for aerospace and automotive applications, as well as in sporting goods such as high-performance bicycles and racing boats.

    c. **Conductive fibres.** Conductive fibres, such as stainless steel or copper fibres, are used in technical textiles for applications such as electromagnetic shielding, heating elements, and sensors.

    d. **Nano fibres.** Nanofibers are ultra-fine fibres with diameters of less than 100 nanometres. They offer unique properties, such as high surface area and high porosity, and are used in applications such as air filtration, wound dressings, and tissue engineering.

3. Specialized manufacturing processes used in technical textiles:

    a. **3D knitting.** 3D knitting is a specialized knitting process that allows for the creation of complex, three-dimensional shapes, and structures. It is often used in technical textiles for applications such as footwear, medical implants, and automotive interiors.

    b. **Electrospinning.** Electrospinning is a process that uses an electric field to create ultra-fine fibres from a polymer solution. It is used to create nanofibers for applications such as air filtration, wound dressings, and tissue engineering.

    c. **Coating and lamination.** Coating and lamination processes are used to add functional properties to textiles, such as water resistance, flame resistance, or antimicrobial properties. These processes involve the application of a layer of material, such as a polymer or metal, onto the surface of the textile.

    d. **Chemical treatments.** Chemical treatments, such as dyeing or finishing processes, are used to modify the surface properties of textiles. For example, a textile may be treated with a hydrophobic coating to repel water or a flame-retardant chemical to improve its fire resistance.

4. There are many types of technical textiles, each with unique properties and functions:

    a. **Protective textiles.** These are textiles designed to provide protection against various hazards, such as fire, chemicals, extreme temperatures, and physical impacts. Examples include body armour, firefighter gear, chemical-resistant clothing, and heat-resistant fabrics.

b. **Medical textiles.** These are textiles used in medical applications, such as wound dressings, surgical gowns, and implantable textiles. Medical textiles may be designed to be antimicrobial, biocompatible, or to provide other functional properties.

c. **Agro textiles.** These are textiles used in agricultural applications, such as crop protection, irrigation, and livestock management. Examples include shade nets, insect nets, and geotextiles for erosion control.

d. **Sports textiles.** These are textiles designed for use in sporting goods, such as clothing, footwear, and equipment. Examples include moisture-wicking fabrics, breathable materials, and impact-resistant textiles.

e. **Geotextiles.** These are textiles used in civil engineering applications, such as road construction, erosion control, and soil stabilization. Examples include geotextile fabrics for filtration and separation, as well as geo-composites for drainage and reinforcement.

f. **Automotive textiles.** These are textiles used in automotive applications, such as seat covers, airbags, and sound insulation. Examples include fabrics with high abrasion resistance, low flammability, and improved acoustics.

g. **Smart textiles.** These are textiles with integrated electronics, sensors, or other advanced materials that allow for the monitoring or control of various properties, such as temperature, moisture, or movement. Examples include wearable fitness trackers, smart clothing for athletes, and interactive textiles for interior design.

5. Protective technical textiles are designed to protect the wearer from various hazards such as fire, chemicals, extreme temperatures, and physical impacts. In the context of this exercise, protective technical textiles best fit the use-case highlighted in the above sections. These are some common types of protective technical textiles:

    a. **Fire-resistant textiles.** These are textiles designed to provide protection against fire and flames. They are used in applications such as firefighting gear, industrial workwear, and military uniforms. Examples of fire-resistant fibres used in textiles include aramid fibres (e.g., Kevlar), carbon fibres, and fiberglass.

    b. **Chemical-resistant textiles.** These are textiles designed to provide protection against hazardous chemicals and liquids. They are used in applications such as chemical processing, oil and gas exploration, and medical and pharmaceutical industries. Examples of chemical-resistant fibres used in textiles include polyethylene, polyvinyl alcohol, and polypropylene.

    c. **Ballistic-resistant textiles.** These are textiles designed to provide protection against ballistic threats, such as bullets and shrapnel. They are used in applications such as military and law enforcement gear, as well as in body armour for civilians. Examples of ballistic-resistant fibres used in textiles include aramid fibres (e.g., Kevlar), high-density polyethylene (HDPE), and ultra-high-molecular-weight polyethylene.

    d. **Cut-resistant textiles.** These are textiles designed to provide protection against sharp objects, such as knives and glass. They are used in applications such as industrial workwear, food processing, and medical and veterinary gloves. Examples of cut-resistant fibres used in textiles include high-performance polyethylene, aramid fibres, and stainless steel.

e. **Impact-resistant textiles.** These are textiles designed to provide protection against impact and blunt force trauma. They are used in applications such as sports and protective gear, military and law enforcement equipment, and construction workwear. Examples of impact-resistant materials used in textiles include foams, gels, and composite materials.

f. **Radiation-resistant textiles.** These are textiles designed to provide protection against ionizing radiation, such as X-rays and gamma rays. They are used in applications such as medical and dental imaging, nuclear power plants, and space exploration. Examples of radiation-resistant materials used in textiles include lead and lead compounds, as well as non-toxic alternatives such as tungsten and bismuth.

6. In addition to a combination of the above parameters, disaster responders may require features like high-visibility and breathability in their suits as they may need to work in low-light conditions or in hot and humid environments during search and rescue operations.

7. Thus, in summary, technical textiles are vital to disaster responders as they ensure maximum:

    a. **Protection.** Disaster responders often face hazardous environments and situations that can pose a risk to their safety and health. Technical textiles, such as flame-resistant, chemical-resistant, ballistic-resistant, and cut-resistant textiles, can provide protection against such hazards.

    b. **Functionality.** Disaster responders need to be able to perform their duties effectively and efficiently, and technical textiles can help them do so. For example, high-visibility textiles can help responders be easily located, breathable and moisture-wicking textiles can help regulate body temperature, and lightweight and flexible textiles can allow for greater mobility.

    c. **Durability.** Disaster responders need gear that can withstand the rigors of their work, which often involves harsh conditions and heavy use. Technical textiles are designed to be durable and resistant to wear and tear, ensuring that they can withstand the demands of disaster response work.

    d. **Adaptability.** Disaster responders need gear that can adapt to changing situations and environments. Technical textiles can be designed to be versatile and multi-functional, allowing them to be used in a variety of situations and contexts.

    e. **Efficiency.** Disaster response work often requires a rapid response and quick deployment. Technical textiles can be designed to be lightweight and portable, making them easy to transport and deploy quickly.

8. The need for technological intervention is of utmost importance for successful enhancement of rescue personnel performance. On the basis of the above-mentioned need-feature mapping, technological capabilities that have the capacity to address the needs, and their relevance to the end-user are mapped in the following Prioritization Matrix[21]. The various layers of this matrix are:
    a. Feature and its description
    b. Technological capabilities and the specific layers that have the said features
    c. Relevance in terms of the end adopter to tie the need with the end user

[21] This applies to all the three Prioritization Matrices in this document.

9. Technology Stack

The below technology stack categorizes different features of technical textiles, the advanced materials used, and the manufacturing processes involved in fabrication of the same.

Feature	Category	Advanced Material	Advanced Processing
Protection	Fire Resistance	-Aramid, Carbon Fibres, Fiberglass -Flame Retardant Coating	-Jacquard weave - Laminating and Bonding
	Chemical Resistance	-Barrier Fabrics (PE, PP, PVC) -Coatings and Laminates Chemical Resistant Fibres (PTFE, PVDF)	-Tight Weave -Polymer Extrusion
	Ingress/Cut Resistance	-High performance Fibres (Para-aramid, UHMWPE) -Composite Materials	-Knitting and Weaving
	Radiation Resistance	-Barium Sulfate, Metal Oxide coatings (Sn, Zn) -Carbon Nanotubes -Electromagnetic Shielding materials (Copper, Nickel)	-Laminating Lead sheets on fabric substrates
	Water Resistance	-Waterproof Membranes -Water repellent coatings -Hydrophobic Fibres	-Durable Water Repellent treatment -Seam Sealing
	Microbial Resistance	-Antimicrobial Agents -Nanofiber Membranes made of Electro spun polymers	-Ultra-Violet Resistant fibres
Functionality	Breathability (Air)	-Microfibers -Moisture Wicking Materials – Polyester, Nylon -Ventilation systems – mesh panels, air vents -Breathable Membranes – ePTFE, PU	-Open Weave
	Thermoregulation (Temperature)	-Phase Change Materials (PCM) -Thermoregulating fibres – Outlast, ThermoCool -Insulation – Synthetic fibres -Nano -porous Membranes	-Microencapsulation -Chemical Treatment -Moisture Management
	Visibility (Light)	-Reflective Materials -Fluorescent Materials -Photo-Luminescent Materials	-Embedded LED Lighting -Embroidered Chevrons
	Durability (Life)	-High-strength fibres – Dyneema, Spectra - Coatings and Laminates – Teflon, PVC, PU	-Multi-layer Constructions -Seamless Knitting and Bonding -Surface Treatments
	Light weight (Portable)	-High-performance fibres with high Strength to Weight ratios -Microfibers – Lightweight fabrics -Membrane Laminates – thin films -Lightweight foam, Mesh inserts	-Nanotechnology – Nanofibers woven into lightweight fabrics high surface area and excellent mechanical properties

10. Prioritization Matrix

#	Feature Requirement	Description	Priority		Capability
			Adopter Decision-Making Tier 1	**Adopter Decision-Making Tier 2**	
1	**Smart Temperature**	Smart temperature textiles are designed to regulate the temperature of the wearer by incorporating materials that respond to changes in temperature or humidity. They can also include heating or cooling elements that can be controlled by sensors or a user interface.	Strategic Tier. *IG/DIG* Priority Level: **High**: Disaster teams may work in environments with extreme temperatures, and smart temperature textiles can help regulate their body temperature for improved comfort, safety and endurance.	Operational Tier. *CO* Priority Level: **High**: If the responder is working in a hot and humid environment, the smart textile can help to cool them down and prevent heat exhaustion.	**Dual Cooling Capability**: In a first step, melting energy absorption delivers instant contact cooling before the first sign of sweat and delays the build-up of heat, followed by a vaporizing energy action that mimics the skin's thermal regulating system by providing continuous evaporative cooling if the body is hot and sweaty. Instantly cool to the touch, the components synergistically recharge the surface layer ensuring a consistently cool, dry, and comfortable body climate.
2	**Abrasion Resistance**	Abrasion-resistant textiles are designed to withstand wear and tear from friction, rubbing, or scraping. They can incorporate materials including high-strength fibers and can also feature reinforced stitching or coatings that enhance their durability.	Strategic Tier. *DIG* Priority Level: **High**: Disaster teams may encounter sharp objects or rough terrain during rescue operations, and abrasion-resistant textiles can protect them from injury and extend the life of their clothing.	Tactical Tier. *Inspector* Priority Level: **High**: An abrasion-resistant fabric can protect responders from tears and abrasions from sharp objects when working in a collapsed building and debris.	**Synthetic fibers** such as nylon, polyester, or Kevlar. These fibers are known for their strength, toughness, and resistance to abrasion. They may be incorporated into the textile through a variety of techniques such as weaving or knitting, and may be blended with natural fibers such as cotton to create a textile with a unique balance of properties

#	Feature Requirement	Description	Priority		Capability
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2	
3	**Anti-Microbial**	Anti-microbial textiles are designed to inhibit the growth of bacteria, viruses, or other microorganisms that can cause infections or illness. They can incorporate materials that are naturally anti-microbial or can feature coatings or treatments that prevent the growth of microorganisms.	Strategic Tier. *IG, DIG* Priority Level: **High**: SAR teams and responders must be in optimal, healthy conditions throughout, avoid contamination/microbial diseases.	Tactical Tier. *AC, Inspector* Priority Level: **Medium**: Disaster responders could be exposed to harmful bacteria, viruses, or other pathogens during rescue operations.	**Silver-based Ingredients:** The silver-based ingredients used in anti-microbial smart textiles are effective against a wide range of harmful microbes, including bacteria, viruses, and fungi. These ingredients work by disrupting the cellular structure of microbes, preventing their growth and reproduction.
4	**Durable Water Repellent**	Durable water-repellent textiles are designed to resist the penetration of water or other liquids. They can incorporate hydrophobic materials that repel water and can also feature coatings or treatments that enhance their water resistance.	Operational Tier. *CO* Priority Level: **Medium**: Battalion teams may work in wet or humid environments, and durable water-repellent textiles can keep them dry and comfortable.	Tactical Tier. *Inspector* Priority Level: **High**: Durable water-repellent fabric can prevent water from seeping through during a rescue operation in a flood or storm.	**Microscopic Hydrophobic 3D Surface**: Building a microscopic 3D surface structure on the textile's surface creates a hydrophobic barrier that minimizes contact points between the textile and water. When water encounters the textile, the surface tension of the liquid causes it to bead up and roll off the surface of the textile, rather than soaking into the fabric. This not only keeps the wearer dry and comfortable but also helps to prevent damage to the textile from exposure to moisture.

#	Feature Requirement	Description	Priority		Capability
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2	
5	**Odor Resistance**	Odor-resistant textiles are designed to prevent the buildup of unpleasant odors that can result from sweat, bacteria, or other factors. They can incorporate materials that are naturally odor-resistant or can feature coatings or treatments that prevent odor buildup.	Tactical Tier. *Inspector* Priority Level: **Medium**: Disaster rescue workers may work long hours in challenging conditions, and odor-resistant textiles can prevent unpleasant odors from building up and improving comfort.		**Volatile Organic Compounds (VOCs) Absorption**: smart textiles with this feature also provide dual-action odor resistance. The textiles are designed to adsorb Volatile Organic Compounds (VOCs) that contribute to unpleasant odors, keeping the clothing fresh and clean even after prolonged use.
6	**Air-Dry Capability**	Air-dry capable textiles are designed to dry quickly when exposed to air or other sources of ventilation. They can incorporate materials that are lightweight and breathable and can also feature moisture-wicking properties that help to remove moisture from the wearer's skin.	Operational Tier. *CO* Priority Level: **Low:** SAR team responders may get wet during rescue operations or sweat during physical exertion, and air-dry capable textiles can help them stay dry and comfortable.	Tactical Tier. *AC/Insp.* Priority Level: **High/Medium:** Air-dry capable clothing can prevent responders from getting chilled after working long hours in wet conditions.	**Synthetic Fibers**: High-performance synthetic fibers such as polyester, nylon, or elastane, which have a high surface area-to-volume ratio and are hydrophobic, meaning they repel water. These fibers are often combined with natural fibers such as cotton, which are highly absorbent, to create a textile that is both quick-drying and comfortable to wear.

C.3 Block 2: Exoskeletons

1. **Background.** The word 'exoskeleton' has been originally defined as a rigid external structure that surrounds and supports the body of an organism. It is commonly found in invertebrates such as insects, crustaceans, and molluscs, but can also be found in some vertebrates such as turtles.

2. **Functions.** Exoskeletons provide several benefits to organisms, including protection against predators, support for movement, and mechanical support for body tissues. In some cases, exoskeletons can also provide load assistance by reducing the amount of work that muscles have to do to support the weight of the body or any external loads that the organism is carrying.

3. **Composition.** Exoskeletons are typically made of chitin, a tough, lightweight, and flexible material that provides both strength and flexibility. The shape and structure of the exoskeleton can vary depending on the needs of the organism. In insects, for example, the exoskeleton is divided into segments and joints that allow for flexible movement. In crustaceans, the exoskeleton is thicker and provides more rigid support.

4. In recent years, exoskeletons have also been developed as wearable devices to assist humans with load-carrying tasks. These exoskeletons typically use mechanical systems and sensors to provide support and reduce the load on the user's muscles and joints, which can help to prevent injuries and improve endurance during physical tasks. As discussed in the above sections, enhanced endurance and load-bearing capacity is key for a disaster responder to maximize individual operational efficiency and therefore Load-assisting exoskeletons address the above in the most optimal manner.

5. **Load-assisting exoskeletons.** Wearable devices that are designed to provide mechanical support to the user's body, augment muscular strength and reduce the physical strain associated with carrying heavy loads or performing repetitive tasks. For troopers, responders, soldiers, the exoskeleton:
    a. Increases load bearing capacity of the individual concerned;
    b. Reduces chances of injury due to even distribution of load;
    c. Reduces fatigue and exertion for personnel during operations.

6. These exoskeletons can be classified into several different types based on their design and function. Based on how they are powered and actuate movements, they can be classified as Active and Passive and a hybrid of the above two systems is called Semi-Passive or a Powered-Assist Exoskeleton.

    a. **Active exoskeletons (Powered).** These exoskeletons use powered motors or actuators to actively assist the user's movements. They can provide adjustable levels of support and control and can be customized for different types of tasks and users. Active exoskeletons are more complex than passive exoskeletons and require more training and maintenance.

    b. **Passive exoskeletons (Self-Powered).** These exoskeletons use mechanical structures, such as springs or dampers, to absorb and redistribute loads. They provide a fixed amount of support, and the user's movements are not actively controlled by the device. Passive exoskeletons are typically lightweight and easy to use, but they may not be suitable for all types of tasks or users.

7. Based on the frame design and what parts of the body it augments, they can be classified as –

    a. **Full-body exoskeletons.** These exoskeletons cover the entire body and are designed to support heavy loads and reduce the risk of injury during manual labour tasks. They typically use a combination of passive and active elements to provide support and may include features such as sensors and feedback systems to optimize performance.

    b. **Upper-body exoskeletons.** These exoskeletons are designed to assist with tasks that involve repetitive arm movements, such as overhead work or assembly tasks. They typically consist of an arm support structure and a powered actuator or spring system to reduce the strain on the user's arms and shoulders.

    c. **Lower-body exoskeletons.** These exoskeletons are designed to assist with tasks that involve carrying heavy loads or standing for long periods of time. They typically consist of a leg support structure and a powered actuator or spring system to reduce the strain on the user's legs and lower back.

8. Examples of load-assisting exoskeletons that have been developed for humans include the Hybrid Assistive Limb exoskeleton from Cyberdyne, the XOS 2 exoskeleton from Raytheon, and the Ekso Bionics exoskeleton. These exoskeletons are currently used in a variety of applications, including manufacturing, construction, and military tasks.

9. Problems/ Challenges tackled by the technology**:**

Problem	Description	Category
Assistive Movement	Movement assistance to people suffering from motor disability. Allows unassisted movement	Medical
Rehabilitation	Supporting injured bone joints to regain movement. Usually helpful in spinal cord movement assistance	Medical
Medical care	Help medical staff to be able to lift immobile, elderly, and large-bodies patients much more efficiently and safely. Surgeons may also benefit from exoskeletons in that the technology can enhance their precision without having to resort to surgical robots.	Medical
Weight Offloading	Augment force personnel strength in carrying heavy weights, avoiding fatigue and strain	Military (Relevant to NDRF)
Increased grip	Downscaled industrial exoskeletons that can fit around a hand (much like a glove) can aid workers to get a better grasp of their own tools. This can also help them to be more precise with the operation of the tool, especially for craftsman or artisanal purposes.	Military
Movement Enhancement	Can aid the soldier's movement thereby increasing movement efficiency and less muscle fatigue	Military (Relevant to NDRF)

10. **Technology Stack**

This stack maps the various electro-mechanical sub-systems of an Active and Passive Exoskeleton:

	Active (Powered)	**Passive (Self-Powered)**	
Sensors	Force Sensors Inertial Sensors (Limb Orientation and Acceleration) Joint Angle Sensors (Angle and Position of user's joints) Pressure Sensors Environmental Sensors (Temperature and Humidity)	Joints (Series of Mechanical Linkages) Straps and Harnesses (for a secure and comfortable fit) Connectors and Bolts Material (Carbon Fiber, Aluminium, Titanium)	**Frame**
Control System	Centralized Control Distributed Control PID Control FSM Control [Human-in-Loop with Machine Learning]	Torsion Springs (Even distribution of weight) Extension Springs (Additional Support and Stability) Compression Springs (Absorb and distribute load) Gas Springs (Compressed Gas) Leaf Springs (Stacking Metal Strips)	**Springs**
Actuators	Electric Motors Hydraulic/Pneumatic Cylinders Cable-driven actuators	Hydraulic Dampers (fluid based) Friction Dampers	**Dampers**
Power System	Li-Ion Batteries/Fuel Cells Power Management System	Foam, Gel – Increased comfort and reduce pressure points	**Padding**
Human-Machine Interface	Joystick/Buttons Electromyography (EMG) Sensors Gesture/Voice Recognition Visual Feedback	Braces Supports Additional Straps	**Stabilizers**
Design Configuration: Full-body, Lower-body, Upper-body, Hybrid Exoskeletons			

11. Powered/Active and Self-Powered/Passive exoskeletons can be compared as below:

#	Parameters	Active Exoskeleton	Passive Exoskeleton
1	**Cost**	High due to electronic circuitry, batteries, actuators	Low due to hinge and spring-based mechanism
2	**Load bearing capacity**	High capacity of load bearing due to battery powered assistance	Lower compared to powered, assistance provided by hinge joints that redistributes load
3	**Endurance**	High but depends on battery capacity	Not limited but will depend on user's endurance
4	**Response Time**	Depending on type of sensing system used, there is slight lag between stimulus and response	Low as the movement depends entirely on individual
5	**Maintenance, Repair and Operations**	High due to presence of motors, sensors and circuitry	Lower as functioning based on springs and dampers

Figure 14: *Front and back view of the MAX (Modular Agile eXoskeleton) developed by suitX, a California based Robotics company.*

It combines back, shoulder and leg components to form a lightweight and versatile design for reduced fatigue and minimal injuries.[22]

Figure 15: *A solider performing push-ups with the XOS 2, a second-generation robotics suit developed by Raytheon for the US Army as part of Defence Advanced Research Project Agencies, 'Human Performance Augmentation' programme.*

This wearable robotic suit increases the human strength, agility and endurance capabilities of the soldier inside it. The XOS 2 uses high-pressure hydraulics to allow the wearer to lift heavy objects at a ratio of 17:1 (actual weight to perceived weight). This allows repeated lifting of the load without exhaustion or injury.[23]

[22] SME. *suitX MAX Exoskeleton Augments Wearer While Reducing Risk of Workplace Injury* 17 November 2016https://www.sme.org/suitx-max-exoskeleton-augments-wearer-while-reducing-risk-of-workplace-injury

[23] Army Technology. *Raytheon XOS 2 Exoskeleton, Second-Generation Robotics Suit*. 29 May 2020. https://www.army-technology.com/projects/raytheon-xos-2-exoskeleton-us/

12. Prioritization Matrix

#	Feature Requirement	Description	Priority		Capability
			Adopter Decision-Making Tier 1	**Adopter Decision-Making Tier 2**	
1	**Light weight, Modular, Efficient**	A lightweight exoskeleton will have reduced energy expenditure, increased mobility, greater comfort and flexibility, ease of use and versatility. Modular and efficient designs cater to additional customizations, scalability in weight of load, ease of maintenance, efficient use of resources and cost-effectiveness.	Tactical Tier. *AC/Insp.* Priority Level: **High**: It is critical for the responder to have a lightweight system which is modular and efficient for smoother operations and minimal fatigue. Additionally, higher strength augmentation, increased support and endurance is necessary for sustained hours of activity and greater throughput.	Strategic/Operational Tier. *DIG/CO* Priority Level: **Medium**: Strategic tier requires teams to continue operations until closure, achieve enhanced endurance and load bearing capacities, minimize injuries/fatigue in SAR teams.	Advanced Materials (light weight, high strength): Carbon fibre, Aluminium alloys, Titanium, polymers. 3D printing, CNC machining for precise, durable components Innovative, Ergonomic Frame Design for load distribution, foldable/collapsible for transport, adjustable sizing, padding for fatigue reduction Efficient, Robust power system: Lighter long-lasting batteries/fuel-cells, self-powered for efficiency Efficient Energy storage and release systems – hydraulic accumulators
2	**Strength, Support, Endurance**	Strength: Must be strong enough to handle the additional loads placed upon them. The device must be able to support the weight of the load, as well as the weight of the wearer. Support: Must provide support to the wearer's body to reduce the risk of injury. The device must be able to distribute the load evenly across the wearer's body, avoiding any areas of undue stress or strain. Endurance: Must be able to provide endurance to the wearer, allowing them to perform physically demanding tasks for longer periods without experiencing fatigue. This requires a balance between the weight and size of the exoskeleton, the amount of assistance provided, and the energy efficiency of the device.			

C.4 Block 3: Resilient Communications

1. **Satellite Communication.** Satellite communication systems are wireless communication systems that use satellites orbiting the earth to transmit and receive signals between two or more devices. These systems use satellite frequencies to transmit data or voice signals from one point to another, allowing people to communicate with each other over long distances without the need for physical wires or cables. Satellite communication technology can play a critical role in disaster response efforts, as it provides reliable and resilient communication links that can help coordinate emergency response efforts and provide essential information to affected communities.

    a. **Platform Types.** There are several types of satellite communication platforms that can be used in disaster response efforts. These include:
        i. **Geostationary Satellite Systems.** Geostationary satellites are located in geosynchronous orbit, meaning they remain in a fixed position relative to the Earth's surface. These satellites are often used for voice and data communication links, as well as for video and imagery transmission.
        ii. **Low Earth Orbit (LEO) Satellite Systems.** LEO satellite systems typically orbit at altitudes between 500 and 2000 kilometers above the Earth's surface. These systems can provide high-speed data transmission, as well as Global Positioning System services, and can be used for communication links between first responders and command centers.
        iii. **Medium Earth Orbit (MEO) Satellite Systems.** MEO satellites are located at altitudes of around 10,000 kilometers above the Earth's surface. These systems are often used for navigation and positioning services, as well as for data and voice communication links.
        iv. **High Altitude Platform Systems (HAPS).** HAPS are unmanned platforms, such as balloons or drones, which are used to provide communication links in areas where traditional satellite systems are unavailable or impractical. These systems can be quickly deployed in emergency situations and can provide temporary communication links to support disaster response efforts.

    Each of these systems has its own benefits and limitations, and the choice of system will depend on the specific requirements of the disaster response operation. For example, geostationary satellites can provide continuous communication links over a wide area, but may be affected by weather conditions, while LEO satellites can provide high-speed data transmission and GPS location services but may require a large number of satellites to provide comprehensive coverage.

    b. **Equipment Types.** Apart from the platform, the equipment used for establishing satellite communication can be of different types, as below:

        i. **Satellite Phones.** Satellite phones are handheld devices that connect to satellites to provide voice and data communication links. These devices can be used in areas without cellular coverage or in situations where the cellular network is damaged or overloaded.
        ii. **Mobile Satellite Terminals.** Mobile satellite terminals are larger devices that can be used to establish a satellite communication link between a base station or command center and field personnel. These terminals can be used to provide voice, data, and video communication links.
        iii. **Satellite Modems.** Satellite modems are used to modulate and demodulate data signals for transmission over a satellite link. These modems can be integrated into other communication equipment, such as laptops, to enable satellite-based communication.

iv. **Antennas.** Antennas are used to transmit and receive signals to and from satellites. Depending on the application, different types of antennas may be used, such as dish antennas, patch antennas, or helical antennas.
v. **Satellite Ground Stations.** Satellite ground stations are used to receive and transmit signals to and from satellites. These stations can be located at fixed locations or can be mobile, depending on the specific requirements of the disaster response operation.

c. Benefits of Satellite Communication Systems:

i. **Coverage**. Satellite communication systems can provide coverage in areas where terrestrial communication systems are damaged or unavailable.
ii. **High-speed data transfer.** Satellite communication systems can transmit large amounts of data quickly, making them useful for transmitting critical information, such as maps, images, and video.
iii. **Flexibility**. Satellite communication systems are flexible and can be quickly deployed to support disaster response efforts.
iv. **Reliability**. Satellite communication systems are less susceptible to damage from disasters, making them a more reliable communication option during and after disasters.

d. Limitations of Satellite Communication Systems:

i. **Cost.** Satellite communication systems can be expensive to deploy and maintain, making them a less practical option for some organizations.
ii. **Complexity.** Satellite communication systems can be complex to set up and maintain, requiring specialized knowledge and expertise.
iii. **Limited bandwidth.** Satellite communication systems often have limited bandwidth, which can limit the amount of data that can be transmitted.
iv. **Latency.** Satellite communication systems can suffer from latency, which can make real-time communication difficult.

e. Challenges of Satellite Communication Systems:

i. **Power supply.** Satellite communication systems require a reliable power supply, which can be a challenge in disaster-affected areas.
ii. **Interference.** Satellite communication systems can be susceptible to interference from other satellite signals or atmospheric conditions, which can affect the quality of the communication link.
iii. **Availability.** During a disaster, satellite communication systems may be in high demand and may not be available due to capacity limitations.
iv. **Access.** Some countries may not have access to certain satellite communication systems due to regulations or other restrictions.

2. **Radio Communication.** Radio communication systems are wireless communication systems that use radio waves to transmit and receive signals between two or more devices. These systems use radio frequencies to transmit data or voice signals from one point to another, allowing people to communicate with each other over long distances without the need for physical wires or cables. Radio communication technology can also play a critical role in disaster response efforts, as it provides reliable and flexible communication links that can help coordinate emergency response efforts and provide essential information to affected communities.

a. **Types of Radio Communication Systems**:

i. **VHF (Very High Frequency) and UHF (Ultra High Frequency) Radio Systems.** These radio systems operate in the 30 MHz to 1 GHz frequency range and are commonly used for voice communication links between first responders, command centers, and other personnel involved in disaster response. VHF and UHF radio systems are often used in situations where cellular networks are not available or are overloaded.
ii. **HF (High Frequency) Radio Systems.** HF radio systems operate in the 3 to 30 MHz frequency range and can provide long-range communication links in remote or disaster-affected areas. These systems can be used for voice and data communication links and can be particularly useful in situations where satellite communication systems are not available or are impractical.
iii. **Digital Radio Systems.** Digital radio systems use digital signal processing techniques to provide enhanced voice and data communication links. These systems can provide improved audio quality, encryption capabilities, and advanced features such as location tracking and group calling.
iv. **Amateur Radio Systems.** Amateur radio systems, also known as ham radio systems, are operated by licensed amateur radio operators who provide communication support during disasters and emergencies. These systems can provide long-range communication links and can be used to support coordination between first responders and other personnel involved in disaster response.

b. **Benefits of Radio Communication Systems**:

i. **Reliable**. Radio communication systems are often more reliable than cellular networks, as they do not rely on infrastructure such as cell towers that may be damaged or destroyed in a disaster.
ii. **Flexible**. Radio communication systems can be used in a wide range of situations and environments, including remote areas or areas without cellular coverage.
iii. **Cost-effective**. Radio communication systems can be relatively inexpensive to deploy and maintain, making them a cost-effective solution for disaster response operations.

c. **Limitations of Radio Communication Systems**:

i. **Limited bandwidth**. Radio communication systems often have limited bandwidth, which can restrict the amount of data that can be transmitted over the network.
ii. **Interference**. Radio communication systems can be susceptible to interference from other radio signals, which can affect the quality of the communication link.
iii. **Line-of-sight limitations.** VHF, UHF, and HF radio systems typically require line-of-sight between the transmitting and receiving antennas, which can limit their range and effectiveness in certain situations.

d. **Challenges in Radio Communication Systems**:

i. **Spectrum availability.** Radio communication systems require access to specific frequency bands, and in some cases, these frequencies may be allocated to other users or services. This can create challenges in deploying radio communication systems in emergency situations.
ii. **Power supply.** Radio communication systems require a reliable power supply, which can be a challenge in areas where the electrical grid is damaged or unavailable. Backup power supplies such as generators or batteries may be required.

iii. **Interoperability.** In a disaster response operation involving multiple agencies and organizations, it is important that different radio communication systems can communicate with each other. Ensuring interoperability can be a challenge, particularly if different systems use different frequencies or protocols.
iv. **Training and maintenance.** Deploying and maintaining radio communication systems requires specialized knowledge and expertise. Ensuring that personnel are properly trained, and that equipment is properly maintained can be a challenge, particularly in large-scale disaster response operations.

3. **Private Wireless Networks.** Private LTE and cellular networks are wireless communication networks that use Long-Term Evolution (LTE) and different generations of cellular technology (3G, 4G, 5G) to provide secure and reliable communication services for a specific group of users, such as employees, contractors, or emergency responders. These networks are designed to provide a dedicated and high-performance wireless communication system that can be customized to meet the specific needs of the organization. Private LTE and cellular networks are useful for disaster response because they can provide a dedicated and reliable communication channel for emergency responders to coordinate their efforts in real-time. These networks can be designed to prioritize emergency communication, ensuring that critical messages are delivered quickly and reliably, even when traditional communication systems are disrupted. They can also provide real-time situational awareness and data sharing capabilities, allowing emergency responders to share critical information about the disaster, such as the location of victims, the status of infrastructure, and the location of resources.

    a. **Types of Private Wireless Cellular and LTE Networks**:

        i. **Private LTE networks.** As mentioned earlier, private LTE networks use Long-Term Evolution (LTE) technology to provide secure and reliable communication services for a specific group of users, such as employees, contractors, or emergency responders. Private LTE networks can be deployed in various frequency bands, including licensed, unlicensed, and shared spectrum bands.
        ii. **Private 5G networks.** Private 5G networks use fifth generation (5G) cellular technology to provide a dedicated and high-performance wireless communication system for a specific group of users. Private 5G networks are expected to be used in various applications, including industrial automation, smart cities, and transportation.
        iii. **Private cellular networks.** Private cellular networks use traditional cellular technology, such as 4G LTE, to provide a dedicated and secure communication system for a specific group of users. Private cellular networks are often used in office buildings, hospitals, and other indoor environments.
        iv. **Private virtual networks.** Private virtual networks use software-defined networking (SDN) and network function virtualization (NFV) technologies to create a virtualized private network. Private virtual networks can be used to provide secure communication services for a specific group of users, including remote workers and branch offices.

b. Benefits of deploying a Private Wireless Network:

i. **Enhanced Security.** Private wireless networks are designed to provide enhanced security, privacy, and control over the communication services, making them less vulnerable to cyber-attacks or eavesdropping. Classic SIM- based security can be used, as well as emerging non-SIM options.
ii. **High Reliability.** Private cellular and LTE networks can be designed with redundant infrastructure, such as multiple network nodes, base stations, and routers, to ensure high availability and reliability of communication services.
iii. **Customization.** Private wireless networks can be customized to meet the specific communication needs of an organization, including coverage area, bandwidth, latency, and data usage. LTE QoS allows for multiple layers of prioritization. It is well standardized and can adapt to the needs of the application. High priority users can be configured for low latency, predictable outcomes and others be best- effort throughput.[24]
iv. **Improved Efficiency.** Higher spectral efficiency, private wireless networks can provide faster communication services, low latency, and high throughput rates compared to public networks, which can result in improved productivity and operational efficiency.
v. **Cost-effective.** Private wireless networks can be more cost-effective than traditional communication systems, especially in areas where public networks are not available, or the cost of public network usage is high.
vi. **Ease of Deployment.** Private wireless networks can be quickly deployed in various environments, including indoor and outdoor areas, and can be integrated with other communication systems to provide a seamless user experience.

c. Limitations and Deployment Challenges with Private Wireless Cellular and LTE Networks

i. **High Deployment Cost.** Private cellular and LTE networks require significant capital investment to deploy, including network infrastructure, hardware, and software. This can be a significant challenge for small or medium-sized organizations.
ii. **Spectrum Availability.** Private LTE networks require access to licensed spectrum, which can be expensive and difficult to obtain, particularly in densely populated urban areas where spectrum is in high demand.
iii. **Interference.** Private wireless networks can be subject to interference from other wireless networks, which can affect the quality and reliability of communication services.
iv. **Network Complexity.** Private wireless networks can be complex to design, deploy, and manage, particularly if they involve multiple network nodes, base stations, and routers.
v. **Regulatory Compliance.** Private wireless networks must comply with various regulatory requirements, including spectrum licensing, data privacy, and network security.

4. These communication systems are essential for disaster response because they provide a reliable means of communication in emergency situations when traditional communication systems may be unavailable or disrupted. When natural disasters like earthquakes, hurricanes, or wildfires occur, they can damage or destroy critical infrastructure like power lines, cell towers, and telephone lines, leaving people without a way to communicate with each other.

[24] Brown, Gabriel (2017), A Heavy Reading White Paper. Qualcomm, Inc, available at https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/private-lte-networks.pdf

5. In these situations, Radio/Satellite/Private communication systems can provide a lifeline for emergency responders, allowing them to communicate with each other and coordinate their efforts in real-time. These systems can also be used to broadcast emergency alerts and warnings to the public, helping to keep people informed and safe during a crisis.

6. These communication systems are particularly useful in disaster response because they can be easily deployed and operated by trained personnel, making them ideal for use in remote or hard-to-reach areas. They can also operate independently of the power grid, using battery or generator power, which ensures that they remain operational even in the event of a power outage.

7. Overall, resilient communication systems are a critical tool for disaster response, providing emergency responders with a reliable means of communication when traditional communication systems are unavailable or disrupted.

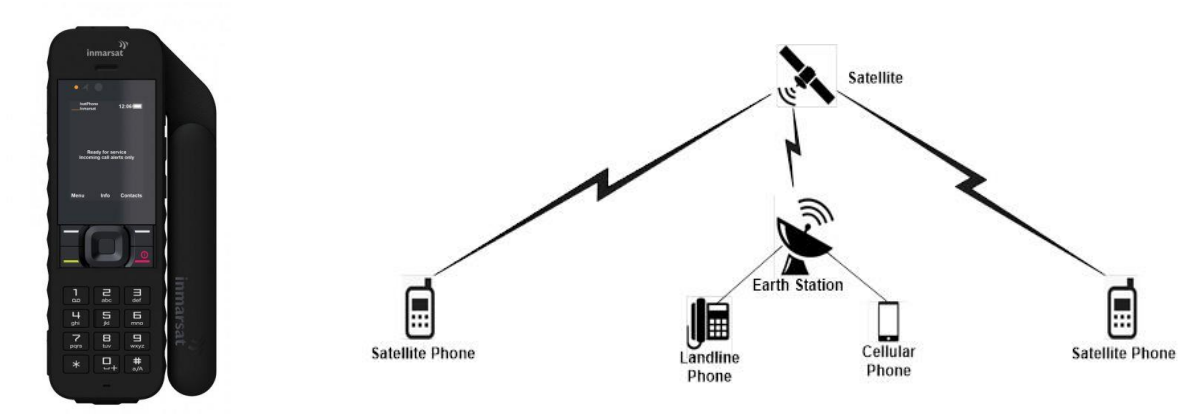


***Figure 16: (L)** Inmarsat Isat2[25], Sat Phone used by the NDRF; **(R)** Depiction on how Satellite phones communicate[26]*

***Figure 17: (L)** VHF Radio Transceiver Set used in operations[27]; **(R)** Private 4G LTE Network-in-a-Box[28]*

[25] Inmarsat. *IsatPhone 2*. https://www.inmarsat.com/en/solutions-services/isatphone-2.html
[26] Phil Sherrod W4PHS. Satellite Phones. Version 1.5 http://www.philsherrod.com/hamradio/Satellite_Phones.pdf
[27] ICOM America. IC-2300H VHF FM Mobile Transceiver.
https://www.icomamerica.com/en/products/amateur/mobile/2300H/default.aspx
[28] Lekha Wireless Solution. https://www.lekhawireless.com/

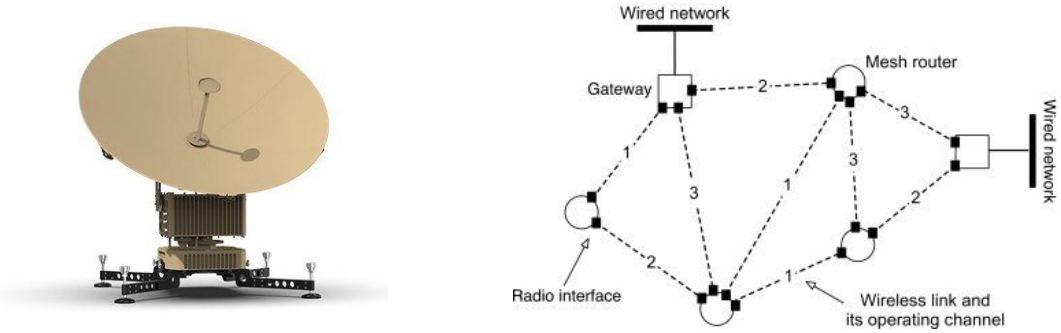


***Figure 18: (L)** VSAT Ku-Band Quick Deployment Antenna; **(R)** A multi-radio wireless mesh network[29]*

8. The below Technology Stack for Resilient Communications depicts different emerging communication technologies like Satellite, Radio and Private Networks that can be used independently or jointly with each other; that have been mapped to the core functionalities like Redundancy, Interoperability, Scalability, Mobility etc. in the grid.

9. The overlay boxes indicate meshing (multiple, non-hierarchical node network) that can improve Redundancy and Scalability significantly. The green highlights indicate the advantages of the particular technology, while the yellow highlights indicate the limitations of the technology when compared with the others.

[29] Xin She Yang, Su Fong Chien and Tiew On Ting (2015), Bio-inspired Computation in Telecommunication. Available at https://www.sciencedirect.com/book/9780128015384/bio-inspired-computation-in-telecommunications#book-description

10. **Technology Stack**

	Satellite Communication	**Radio Communication**	**Private Networks**
Variants	-Satellite Phones, Modems and Terminals -Quick Deployment Antenna (QDA) -Dual-Mode Phones (Sat/Cellular)	-VHF/UHF Radio sets (2-way, half and full duplex) -Software Defined Radios -Cognitive Radio	Network in a Box -4G LTE -5G Cellular (Licensed Spectrum)
Redundancy	-Multiple Satellite Constellations and Ground Stations - Multiple Frequencies, Antenna types (Helix, Dipole, Patch) and Diversity techniques (path and freq. switching)	-Forward Error Correction (FEC) -Automatic Repeat Request (ARQ)	-Backhaul Connections -MIMO Systems
Interoperability	-Standardized Communication Protocols (CAP) -Common Frequencies -Cross-Platform Compatibility	-Standardized Communication Protocols -Gateways via SDRs	-Pairing with Public Cellular Networks will require permissions and integrations
Scalability	-Bandwidth Allocation -Beamforming -Dynamic Resource Allocation	-Frequency Reuse -Adaptive Modulation and Coding (AMC) -Mobile Base Stations, Repeater	-Network Virtualization -Dynamic Spectrum Sharing
Mobility	-Sat Phones/Terminals, Radio Sets are handheld, lightweight -Antennas for better reception are bulky require time to setup		Rugged units ~20kg
Security	-AES Encryption -Authentication	-Access Control -Frequency Hopping	-AES Encryption -Network Segmentation
Power	-Ext Power Source (Generator) for Antennas, Base stations -Battery Powered variants		- Ext. power source needed
Channels	Voice, Data (Images, Maps), Text, Internet	Voice, Text, Telemetry, GNSS	Voice, Video, Paging, Data (Images)

Mesh Networks enable a self-healing, decentralized architecture

Mesh networks lead to scalability in the communication system

11. **Prioritization Matrix**

#	Feature Requirement	Description	Priority		Capability	
			Adopter Decision-Making Tier 1	**Adopter Decision-Making Tier 2**		
1	**Redundancy**	The system should have redundant components and backup systems to ensure that it can continue to function even if one or more components fail.	Tactical Tier. *AC/Insp.* Priority Level: High: The tactical tier comprising of SAR teams of responders need to have continuous connectivity with minimal failures to ensure real-time communication and transfer of accurate information.	Operational Tier. *CO/2IC* Priority Level: Medium: The Operational tier of Battalion Commanders and 2nd-in-Command need to establish and maintain constant contact with State Authorities that include the District Magistrate, SDRF and other nodal bodies.	**Multiple Antennas:** Using multiple antennas, also known as multiple-input multiple-output (MIMO) systems, is a common technique for redundancy in wireless communication. By sending multiple copies of the same signal from different antennas, the receiver can combine the signals to improve the signal quality and reliability.	**Multiple Frequencies:** Transmitting the same information over multiple frequencies, also known as frequency diversity, is another method of redundancy. By transmitting the same signal over different frequencies, the receiver can choose the frequency with the best signal quality and ignore the others.
2	**Interoperability**	The system should be able to connect with other communication systems, both within and outside the affected area, to facilitate coordination and collaboration between response teams.	Strategic Tier. *DIG* Priority Level: High: The aspect of interoperability that allows connecting local area networks to centralized coordination centers like NDRF HQ, NDMA etc. is key to the Strategic tier of the force.		**Software-Defined Radios (SDRs):** SDRs are radios that can be programmed to work with different communication protocols, allowing them to be used with different systems and devices.	**Interoperability Gateways:** Interoperability gateways are devices that can translate between different communication protocols, allowing different devices to communicate with each other.

#	Feature Requirement	Description	Priority		Capability	
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2		
3	**Flexibility**	The system should be able to adapt quickly to changing conditions, such as power outages or network disruptions, and have alternative means of communication. It must also be easy to carry and port as and when the team is required to mobilize.	Tactical Tier. *AC/Insp.* Priority Level: **High:** Flexibility and resilience in the communication system is imperative for the tactical tier of SAR responders as they require to be on the move during a disaster and this demands easy mobility, minimal disruption, and outages as well as smaller setup time.		**Mobile networks:** Mobile networks are designed to be flexible and adaptable in emergency situations. In the event of a disaster, mobile network providers can deploy mobile cell towers, known as cells on wheels (COWs), to areas where infrastructure has been damaged or destroyed. This allows people to make calls and send text messages even when traditional phone lines are down. **Two-way radios:** Two-way radios are often used by emergency services during disasters because they are reliable and easy to use. They do not rely on traditional infrastructure, so they can work even when phone lines or internet connections are down. They are also portable, so emergency workers can take them with them wherever they go.	**Satellite phones:** Satellite phones are another example of flexible wireless communication during emergencies or disasters. They use satellite technology to communicate, so they can work even when terrestrial infrastructure has been damaged or destroyed. This makes them particularly useful in remote or hard-to-reach areas. **Mesh networks:** Mesh networks are decentralized networks that allow devices to communicate with each other without the need for traditional infrastructure. They can be set up quickly and easily and can work even when internet connections are down. This makes them particularly useful during disasters when traditional infrastructure may be damaged or destroyed.

#	Feature Requirement	Description	Priority		Capability	
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2		
4	**Resilient Power Supply**	The system should have a reliable power source that can operate independently of the local power grid, such as backup generators or solar power.	Tactical Tier. *AC/Insp.* Priority Level: **High:** Continuous, uninterrupted power supply is a must have for resilient communication during a disaster. These systems must be capable of running on a primary source like Diesel generators or Power grids (if not damaged) and must have a secondary source of power like LiPo battery packs or Solar power options for operating during no primary supply.		**Backup generators:** Backup generators are commonly used to provide power to cell towers during power outages. They can run on diesel, propane, or natural gas, and can provide power for days or even weeks. Cell tower operators often keep a supply of fuel on hand to ensure that generators can keep running during extended outages.	**Battery backups:** Battery backups are commonly used to provide short-term power to wireless communication equipment during power outages. They are designed to keep equipment running for a few hours, giving operators time to switch to other power sources. **Solar power:** Solar panels can be installed on cell towers or other communication equipment, providing a steady source of power even when the grid goes down.
5	**Multiple Channels**	Communication systems should support multiple channels of communication, including voice calls, text messaging, and data services.	Strategic Tier. *DG, IG* Priority Level: **High:** Real-time updates to the force headquarters must be provided in the form of images and videos in addition to voice and text messages for the decision-making tier to get a picture of the ground reality.	Operational Tier.*CO* Priority Level: **Medium:** The Battalion commander and 2IC would be responsible for deploying teams to disaster sites and would require real-time info via multiple channels from the tactical teams.	**Voice communication:** It is useful for relaying critical information and coordinating emergency response efforts. **Video/Image Transfer:** Images and videos can depict a better picture of the on-ground situation despite having larger bit size and requiring larger data transfer rates.	**Text messaging:** Text messaging is a reliable form of communication that can work even when voice communication is disrupted. It can be used to send short messages quickly and efficiently and is particularly useful when phone lines are overloaded. **Social media:** Social media platforms can be used to quickly disseminate information during emergencies or disasters

#	Feature Requirement	Description	Priority		Capability	
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2		
6	**Priority Access**	The system should have mechanisms in place to ensure that emergency responders and other critical personnel have priority access to the network during a disaster.	Operational Tier. *CO/2IC* Priority Level: **High:** There must exist a feature in the communication system that prioritizes information communicated by critical individuals that include responders, relief providers and survivors (in case of a public network).		**Preemptive access:** Preemptive access is a method of prioritizing emergency communication by preempting non-emergency communication. This means that when an emergency call is made, it will take priority over any other ongoing communication, and the non-emergency communication will be temporarily interrupted. **Quality of Service (QoS) prioritization:** Quality of Service prioritization is a method of prioritizing emergency communication by assigning it a higher priority level than non-emergency communication. This ensures that emergency communication will have access to a larger share of the network's resources, such as bandwidth, than non-emergency communication.	**Dynamic spectrum sharing:** Dynamic spectrum sharing is a method of prioritizing emergency communication by dynamically reallocating unused spectrum to emergency communication during a disaster. This ensures that emergency communication has access to more spectrum than non-emergency communication when it is needed the most. **Geofencing:** Geofencing is a method of prioritizing emergency communication by defining geographic areas where emergency communication will take priority over non-emergency communication. This allows emergency responders to communicate more effectively and ensures that emergency communication will not be disrupted by non-emergency communication in the affected area.

PART D | DEMONSTRATION | FIELD TERRAINS AND CONDITIONS

D.1 Context and Approach

1. **Partnership.** AGNIi Mission has continued to strengthen its long-lasting partnership with the National Disaster Response Force (NDRF), the world's single largest force dedicated to disaster response. The aim of the partnership is to technologically advance, operationally transform and upgrade the NDRF via Indian emerging innovation. AGNIi Mission has committed to the integration and absorption of the most novel innovations in the realm of disaster response which will contribute to greater accuracy and comprehensiveness in the assessment and delivery of disaster response. The technologies will bolster the existing capabilities of the force by augmenting expertise in the realm of Situational Awareness, Field Capabilities, Communications and Training of Force.

2. The Partnership between AGNIi Mission and NDRF is intended to identify and engage technology most relevant to the Force's needs: informing and supporting NDRF modernisation and acquisition decisions, aligned to the Hon'ble Prime Minister's Aatmanirbhar Bharat priority and the Government's Empowered Technology Group initiative. AGNIi Mission identified and evaluated the pain points that NDRF presently faces and converted them into technology stacks and capability maps that could be implemented. Outreach activities, persistent partnership along with stakeholder management with the help of AGNIi Mission were also discussed with the senior leadership of NDRF.

3. **Field Understanding.** The AGNIi Mission's field work with the NDRF began in Feb 2021 when the Chamoli glacial cloudburst occurred that led to catastrophic floods and landslides which claimed more than 200 lives. AGNIi was called in to support the NDRF with deployment-ready emerging technologies that could assist the responders in search and rescue, real-time. Surveillance drones, robots and other technologies were used by troopers at Chamoli. Nano-drones proved to be effective in localized surveillance within the Tapovan tunnel for identification of bodies of deceased labourers from the 13MW Hydroelectric power plant.

4. **Technology Demonstration.** The AGNIi Mission continues to work with NDRF personnel across different tiers in understanding pain-points, operational scenarios and develop technology stacks that can address the problems. On 10th Jan 2022, AGNIi hosted a virtual technology showcase with NDRF where 20+ different technologies were showcased to the Strategic tier (DG, IG, DIGs) and all Battalion Commanders virtually. Certain technologies from these were shortlisted for field technology demonstrations that test the technology in ground-like situations.

Figure 19: *NDRF-AGNIi Virtual Technology Showcase*

5. **Field Technology Showcase.** Subsequently, the AGNIi Mission in collaboration with NDRF organised two Field Technology Showcases in February 2022 and May 2022 at the 11th Battalion, Varanasi and the 5th Battalion, Pune respectively.

6. The Field Technology Showcase finds its base in the Diffusion of Innovation theory, more commonly known as the Rogers' Curve. As per the theory, adoption of new ideas and products do not happen simultaneously in society but follow a layered approach. This is because segments of population have different characteristics that situate them in different categories, depending on when they adopt an innovation. Earliest adopters are Innovators, next being the Early Adopters who are opinion leaders and embrace the opportunity for change and modernization. The Field Technology Showcase is situated between the Early Adopters and the Early Majority. The Early Adopters can act as pioneers for the Early Majority. The AGNIi Mission intends to collaborate with these Early Adopters and have Field Technology Showcases to establish the capabilities of emerging technologies in solving real world problems. In the realm of disaster response, the National Disaster Response Force is one such Early Adopter.

Figure 20: *NDRF and AGNIi members in a rescue power boat at Jadhavwadi Lake, Pune*

7. Everett Rogers in his seminal work Diffusion of Innovations[30] stated that the perceived attributes of innovation (characteristics of innovations, as perceived by individuals) play an important role in determining the rate of adoption of innovation. According to Rogers, there are five important attributes of innovation, these include:

    a. **Relative Advantage:** Refers to the degree to which an innovation is perceived as better than the idea it supersedes. The numerous factors by way of which the degree of relative advantage can be measured include – economic terms, social prestige factors, convenience, and satisfaction.

    b. **Compatibility:** Refers to the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters.

    c. **Complexity:** Refers to the degree to which an innovation is perceived as difficult to understand and use. Some innovations are easy to understand and hence, easily adopted. Meanwhile, others may not be very straightforward, which slows the adoption process.

    d. **Trialability:** Refers to the degree to which an innovation may be experimented with on a limited basis.

    e. **Observability:** Refers to the degree to which the results of an innovation are visible to others. The ease with which individuals are able to see the results of an innovation has a direct impact on the probable likelihood of their adoption.

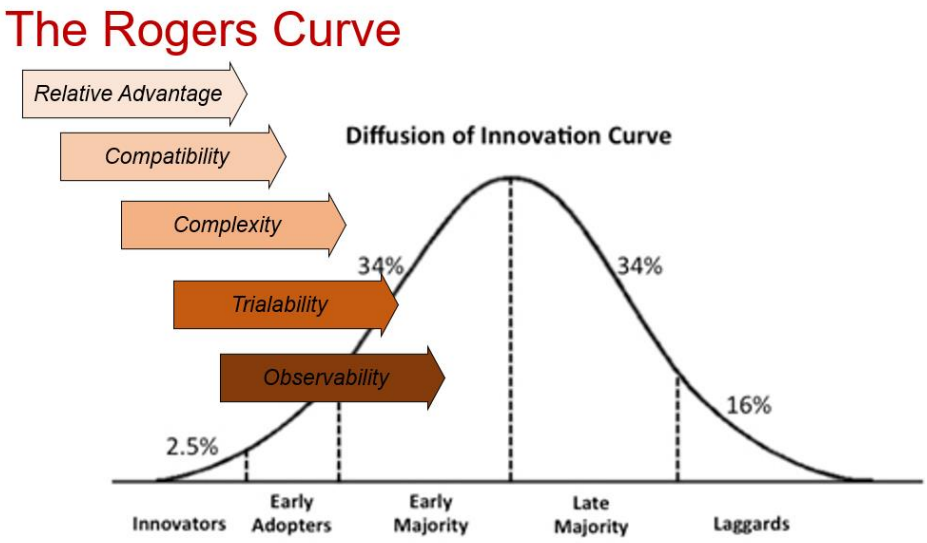


Figure 21: *Characteristics of Innovations and the Diffusion Curve, Everett Rogers, 1962*

8. The perceived attributes of innovation are instrumentally important. This is because the end adopters in this case are primarily disaster response forces and there exist information asymmetries with respect to both functionalities and the benefits of technology innovation. In this context, one of the key objectives of the FTS is to exhibit and contextualise the above attributes of innovation both to the decision makers and the end adopters.

[30] Rogers, E. M. (1962). *Diffusion of Innovations*. New York, Free Press of Glencoe.

9. In the below sections, adoption lever grids explain why and how each of these parameters were showcased at the AGNIi Field Technology Showcases.

D.2 Technical Textile-based Uniforms

1. Across consultations with the AGNIi team, NDRF expressed an interest in redesigning the combat and official uniform by incorporating technical textiles in the fabrication of the material.

2. **NDRF Requirements.** Following consultations with NDRF leadership (from Director-General to Deputy Inspector-General tier) and as per directions received from DIG Provisioning, the following requirements for the field uniform were determined:

    a. *Functional Requirements:*

        i. *Smart Temperature:* Body temperature control, whereby both overheating and feeling chilly are problematic, the proposed fabrics constantly regulate the skin temperature with a dual cooling capability. In a first step, melting energy absorption delivers instant contact cooling before the first sign of sweat and delays the build-up of heat, followed by a vaporizing energy action that mimics the skin's thermal regulating system by providing continuous evaporative cooling if the body is hot and sweaty. Instantly cool to the touch, the components synergistically recharge the surface layer ensuring a consistently cool, dry, and comfortable body climate.
        ii. *Anti-Microbial:* Hybrid product composition combining silver-based ingredients, dual-action odour resistance by antimicrobial and Volatile Organic Compounds (VOCs) adsorption.
        iii. *Durable Water Repellent (DWR):* Builds a microscopic hydrophobic 3D surface structure to minimize contact points and provide durable water repellence.

    b. ***Solution Specification:***

        i. Fresh Uniform (Silver-based Antimicrobial[31] and Odor Control):
            1) Breathable fabric
            2) Antimicrobial properties
            3) Body odour resistant

        ii. Water Repellent Uniform:
            1) Promotes a soft hand and preserves perfect breathability
            2) High abrasion resistance
            3) Air–dry capability

[31] If a material is not inherently antimicrobial, the different types are obtained either by mixing antimicrobial additives into the bulk material, or through direct physical modification (e.g. altered roughness) or chemical modification (e.g. attachment of a biocide) to the surface. The biocidal properties of copper, zinc and silver (amongst other metals) are exploited in commercial antimicrobial additives and in ongoing research, with silver a well-established choice. [Source: Turner, R.D., Wingham, J.R., Paterson, T.E. et al. Use of silver-based additives for the development of antibacterial functionality in Laser Sintered polyamide 12 parts. Sci Rep 10, 892 (2020). https://doi.org/10.1038/s41598-020-57686-4].

c. ***Purpose.*** The below features and specifications will be incorporated:

i. *NDRF Combat Uniform*:

1) Fabric Content: Ripstop, Cotton/Polyester (68/30) with 2 % elastane (GSM-220)
2) Colour: As per print approved by the NDRF
3) Technical Features: Anti-microbial, Anti-odour, Smart temp., DWR- Durable Water-resistant

ii. *NDRF Official Uniform*:

1) Fabric Content: Plain/Jacquard weave, Cotton/Polyester (68/30) with 2 % elastane (GSM-220)
2) Colour: Navy Blue
3) Technical Features: Anti-microbial, Anti-odour, Smart Temperature

iii. The NDRF officers below are wearing the two currently used uniforms: official uniform and combat uniform. The official uniform is shown on the left and the combat uniform is depicted below on the right.

Figure 22: (L) *NDRF Official Uniform;* ***(R)*** *NDRF Field/Combat Uniform (5BN Pune)*

3. Performance Matrix

#	Feature Requirement	Description	Priority		Capability	Showcase Indication
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2		
1	**Smart Temperature**	Smart temperature textiles are designed to regulate the temperature of the wearer by incorporating materials that respond to changes in temperature or humidity.	Strategic Tier. *IG, DIG* Priority Level: **High**	Operational Tier. *CO* Priority Level: **High**	**Dual Cooling Capability**: In a first step, melting energy absorption delivers instant contact cooling before the first sign of sweat and delays the build-up of heat, followed by a vaporizing energy action that mimics the skin's thermal regulating system by providing continuous evaporative cooling if the body is hot and sweaty.	The showcase demonstrated fabric with inherent dual cooling capacity which can regulate temperature of the responders during high temperatures or humid conditions.
2	**Abrasion Resistance**	Abrasion-resistant textiles are designed to withstand wear and tear from friction, rubbing, or scraping. They can incorporate materials including high-strength fibers and can also feature reinforced stitching or coatings that enhance their durability.	Strategic Tier. *DIG* Priority Level: **High**	Tactical Tier. *Inspector* Priority Level: **High**	**Synthetic fibers** such as nylon, polyester, or Kevlar. These fibers are known for their strength, toughness, and resistance to abrasion. They may be incorporated into the textile through techniques such as weaving or knitting and may be blended with natural fibers such as cotton to create a textile with a unique balance of properties.	The showcase demonstrated fabric designed to withstand severe conditions and possible wear and tear due to any friction and scraping. This high-strength fabric was demonstrated and trialed by NDRF personnel and tested for feedback on comfort and ease of mobility.

#	Feature Requirement	Description	Priority		Capability	Showcase Indication
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2		
3	**Anti-Microbial**	Anti-microbial textiles are designed to inhibit the growth of bacteria, viruses, or other microorganisms that can cause infections or illness. They can incorporate materials that are naturally anti-microbial or can feature coatings or treatments that prevent the growth of microorganisms.	Strategic Tier. *IG, DIG* Priority Level: **High**	Tactical Tier. *AC, Inspector* Priority Level: **Medium**	**Silver-based Ingredients:** The silver-based ingredients used in anti-microbial smart textiles are effective against a wide range of harmful microbes, including bacteria, viruses, and fungi.	The showcase demonstrated anti-microbial fabric effective against bacteria/viruses. These were tested and trialed by responders as suggested by DIG NDRF.
4	**Durable Water Repellent**	Durable water-repellent textiles are designed to resist the penetration of water or other liquids. They can incorporate hydrophobic materials that repel water and can also feature coatings or treatments that enhance their water resistance.	Operational Tier. *CO* Priority Level: **Medium**	Tactical Tier. *Inspector* Priority Level: **High**	**Microscopic Hydrophobic 3D Surface**: Building a microscopic 3D surface structure on the textile's surface creates a hydrophobic barrier that minimizes contact points between the textile and water.	The showcase demonstrated water repellent fabric designed with hydrophobic material that repels water. This will be extremely useful during flood water rescue operations as confirmed by DIG NDRF.

#	Feature Requirement	Description	Priority		Capability	Showcase Indication
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2		
5	**Odor Resistance**	Odor-resistant textiles are designed to prevent the buildup of unpleasant odors that can result from sweat, bacteria, or other factors. They can incorporate materials that are naturally odor-resistant or can feature coatings or treatments that prevent odor buildup.	Tactical Tier. *Inspector* Priority Level: **Medium**		**Volatile Organic Compounds (VOCs) Absorption**: smart textiles with this feature also provide dual-action odor resistance. The textiles are designed to adsorb Volatile Organic Compounds (VOCs) that contribute to unpleasant odors, keeping the clothing fresh and clean even after prolonged use.	The showcase demonstrated odor-resistant fabric designed to keep the wearer free from discomfort arising from sweat, bacteria and other elements. The fabric was tested for added comfort and breathability.
6	**Air-Dry Capability**	Air-dry capable textiles are designed to dry quickly when exposed to air or other sources of ventilation. They can incorporate materials that are lightweight and breathable and can also feature moisture-wicking properties that help to remove moisture from the wearer's skin.	Operational Tier. *CO* Priority Level: **Low**	Tactical Tier. *AC/Insp.* Priority Level: **High**	**Synthetic Fibers**: High-performance synthetic fibers such as polyester, nylon, or elastane, which have a high surface area-to-volume ratio and are hydrophobic, meaning they repel water. These fibers are often combined with natural fibers such as cotton, which are highly absorbent, to create a textile that is both quick-drying and comfortable to wear.	The showcase demonstrated quick dry fabric designed to extract moisture from the wearer. This feature adds comfort and preserves breathability.

4. Adoption Levers

The subsequent table in the section enumerates the five important attributes of innovation and how each was conveyed to the decision makers and technology adopters during the showcase of Technical Textiles:

#	Adoption Lever	Technology / Operational Scenario Summary	How did the Showcase achieve this?
1	**Relative Advantage**	NDRF responders need to wade through floodwater, operate in hot and humid environments and harsh conditions. The current NDRF apparel does not support high-tech functional aspects such as water-resistance, enhanced breathability, moisture management and adequate comfortability.	The Officers including DIG (Prov). were shown superior fabric properties of the technical textile in terms of moisture management, abrasion resistance, water repellency etc. during showcases.
2	**Complexity**	Responders must have suits and uniforms that can be quickly worn, easy to equip with the least readiness time. The Strategic tier aims to ensure that in scenario of harsh, hazardous circumstances, the disaster responders wear should not pose hindrance on his/her capabilities. It must completely integrate into their physique and additionally support and enhance their capabilities.	The officers analyzed the design and texture of the fabric and gave feedback on the inherent properties. The feedback on texture, wearability, mobility, design, and print were discussed in detail with the innovator.
3	**Compatibility**	Responders require suits, uniform and other material that complies with their SOPs and maximizes effectiveness during response.	The fabric showcased to DIG Prov. was consistent in design, appearance, and ethos of the NDRF uniform.
4	**Trialability**	During disasters, responder uniforms and suits must be available for continuous, uninterrupted usage and personnel must be well-versed with usage.	The fabric and uniform showcased was tried out by personnel under the directions of DIG Provisioning, NDRF.
5	**Observability**	Responder uniforms often do not show immediate results with moisture management, water repellency, breathability etc. Faster and efficient response of the uniform is key to adoption.	The key technical features like breathability, moisture control, abrasion resistance was showcased, observed and assessed by DIG and other NDRF personnel.

5. AGNIi Mission participated in a two-day-long Annual Conference on Capacity Building for Disaster Response 2022 at Vigyan Bhawan, New Delhi on 6-7th April 2022. The conference was inaugurated by Union Minister of Home Affairs and Union Minister of Cooperation, Sh. Amit Shah. It was attended by DG/ADGs of all State/UTs of the SDRFs, Home Guards, Civil Defence and Fire Services. Dr P K Mishra, Principal Secretary to the Prime Minister of India was the chief guest on the valedictory session conducted on April 8th. AGNIi Mission also delivered a keynote presentation on Emerging Technologies for Disaster Response and conducted a technology display of the most novel solutions pertaining to disaster response.

6. One of the technologies that gained significant traction from the attendees of the conference was Smart Textiles. The technology booth was visited by Director-General, NDRF and the Hon'ble Principal Secretary to the Prime Minister. Later, the Deputy Inspector-General (Prov.) NDRF reached out to the NIFT and Maker Village-incubated start-up for specifications of their offering. This was followed by several additional rounds of discussion with the DG and DIG at the NDRF HQ.

***Figure 23: (L)** Principal Secretary to the PM interacting with the Technical Textiles innovator; **(R)** Technical Textiles booth at the SDRF-NDRF Conference*

***Figure 24:** Example of an innovative fast-dry uniform capable of temperature reduction of upto 3°C*

D.3 Self-Powered Exoskeletons

1. AGNIi Mission organised the first extensive Field Technology Showcase with the 11th Battalion NDRF in Varanasi on 18th Feb 2022. The Showcase comprehensively mapped various Indian emerging technologies to NDRF's mandate, covering Flood Water Rescue, Collapsed Structure Search and Rescue, Rapid Relief Support to victims, Training of Force and Enhanced Situational Awareness during disasters. AGNIi Mission jointly with NDRF designed Showcase scenarios and technical evaluation parameters that were used by the Board of Officers for their real time assessment.

2. AGNIi Mission and 11 BN NDRF conducted the first Showcase of a Passive Exoskeleton at Ganga Ghats, Varanasi. The Field Showcase was conducted with the intention to achieve the following objectives:
    a. Familiarization of force personnel with the equipment;
    b. Interaction of innovators with NDRF decision makers and first responders;
    c. Showcase of exoskeleton under trying conditions to test its viability as a force multiplier;
    d. Assess the load assisting capability of the passive variant of the exoskeleton.

3. In this regard, the exoskeleton was tested for the following:
    a. Comfort Levels: The technology is novel and needs familiarization among users;
    b. Load-Bearing capacity: Force personnel wore the exoskeleton and lifted heavy equipment to test under near-realistic conditions;
    c. Fatigue Reduction and Movement Facilitation: Movement up and down a Ghat hillside to check for reduced effort and lower metabolic stress, prolonging operations.

Figure 25: *DIG (Ops) NDRF trying out the exoskeleton at the banks of river Ganges, Varanasi*

4. The passive exoskeleton was further showcased at NDRF-SDRF Conference on 6th and 7th April 2022 to the officials from NDRF, NDMA, various SDRFs, State Police Forces and other organizations working towards Disaster Response and Relief, among various other technologies. At the conference, the exoskeleton was showcased by the innovator to create wider awareness in the wider ecosystem of Disaster Management. The Director-General of NDRF tried the exoskeleton (upper and lower body) and lifted an NDRF rescue equipment to adeptly test the load-bearing features of the technology. Additionally, the showcase garnered interest from certain SDRFs and further led to the procurement of the exoskeleton by Andhra Pradesh State Disaster Response Force (SDRF).

Figure 26: *DG, NDRF testing the passive exoskeleton at the NDRF-SDRF Conference*

5. The evaluation board from 11 BN Field Showcase observed that in case of the addition of arm-based support, the technology could be made operationally efficient. These inputs were communicated to the innovator for iterative improvements.

6. As per the evaluation board, the low cost of passive exoskeleton allows room for iterative development. A pilot study should be carried out under realistic scenarios where the exoskeleton is tested by personnel under duress of disaster response. Such an approach has the following advantages:

    a. It will enable the force to have confidence in the technology, understand its limitations and usages.

    b. Encourages sustained interaction between the force and innovators that will enable iterative development.

7. **Performance Matrix**

#	Feature Requirement	Description	Priority		Capability	Showcase Indication
			Adopter Decision-Making Tier 1	**Adopter Decision-Making Tier 2**		
1	**Light weight, Modular, Efficient**	A lightweight exoskeleton will have reduced energy expenditure, increased mobility, greater comfort and flexibility, ease of use and versatility. Modular and efficient designs cater to additional customizations, scalability in weight of load, ease of maintenance, efficient use of resources and cost-effectiveness.	Tactical Tier. *AC/Insp.* Priority Level: **High**: It is critical for the responder to have a lightweight system which is modular and efficient for smoother operations and minimal fatigue. Additionally, higher strength augmentation, increased support and endurance is necessary for sustained hours of activity and greater throughput.	Strategic/Operational Tier. *DIG/CO* Priority Level: **Medium**: Strategic tier requires teams to continue operations until closure, achieve enhanced endurance and load bearing capacities, minimize injuries/fatigue in SAR teams.	-Advanced Materials (light weight, high strength): Carbon fibre, Aluminium alloys, Titanium, polymers. 3D printing, CNC machining for precise, durable components -Innovative, Ergonomic Frame Design for load distribution, foldable/collapsible for transport, adjustable sizing, padding for fatigue reduction -Efficient, Robust power system: Lighter long-lasting batteries/fuel-cells, self-powered for efficiency -Efficient Energy storage and release systems – hydraulic accumulators	The exoskeleton demonstrated at the showcase was light-weight (1.8kg), easy to wear and equip (modular) with lower and upper body supports (3.5kg).
2	**Strength, Support, Endurance**	**Strength:** The device must be able to support the weight of the load, as well as the weight of the wearer. **Support:** Must provide support to the wearer's body to reduce the risk of injury. **Endurance:** Must be able to provide endurance to the wearer, allowing them to perform physically demanding tasks for longer periods without experiencing fatigue.				At the showcase, the exoskeleton was used to lift heavy equipment and weights, support provided to user was observed and endurance of wearer was tested.

8. **Adoption Levers**

The subsequent table in the section enumerate the five important attributes of innovation and how each was conveyed to the decision makers and technology adopters during the field showcase of the Passive (Self-Powered) Exoskeleton.

#	Adoption Lever	Technology / Op Scenario Summary	How did the Showcase achieve this?
1	**Relative Advantage**	During rescue operations, responders have to deal with carrying heavy loads (both equipment and clearing of disaster debris for recovery). In the absence of any load distribution mechanisms available to rescuers, this takes a toll on musculoskeletal systems thereby causing injury.	DIG (Ops) and rescue personnel were made to wear the exoskeleton and carry heavy rescue equipment and dummy weights up and down a slope at the showcase site. Through this they were able to compare the ease in carrying additional loads with and without the exoskeleton.
2	**Complexity**	The complexity in such equipment can lead to greater turnaround time during disaster thus delaying response. The complexity in exoskeletons is low due to simpler mechanics and design elements.	It was shown through the showcase that an exoskeleton could be worn by a responder in minimal time and with fairly minimal physical effort.
3	**Compatibility**	Robust SOPs and compliance with them are key during a live disaster situation. The exoskeleton does not alter any current disaster standard operating procedures. It augments the human body in carrying greater weights with ease.	The technology was tried out by NDRF personnel of all tiers at the showcase and the process of usage was an additional overlay on their current manual technique employed to lift heavy objects. It was also identified that for better compatibility, certain features like an attachment for heavier equipment (e.g., Chainsaw) may be explored.
4	**Trialability**	Responders must be well-versed with the technology for them to use and exploit during disaster situations. The design and ease in wear allows for personnel to try and increase comfort in usage.	The officers including the DG and rescuers were made to wear it and try out normal bodily movements as well as lifting sample rescue equipment.
5	**Observability**	The results and perceived weight reduction is not observable and thus needs to be realized and measured by the wearer/user	Upon carrying of dummy loads and heavy rescue equipment, the rescuers wearing the exoskeleton were asked on the perceived weight reduction and realization of effort compared to normal scenarios.

D.4 Satellite Communication and Private Wireless Networks

1. **Satellite Communication.** Among the range of technologies displayed at the NDRF-SDRF Conference on 6th and 7th April 2022 - Satellite Phones, Satellite terminals (dongle) and a Satellite based Location tracker for maritime purposes were showcased by an innovator firm based out of Bangalore.

Figure 27: *DIG Provisioning understanding the different Satellite Comms technologies at the NDRF-SDRF Conference (April 2022)*

2. Among the different satellite-based products, the S-Band Dual-mode Satellite phone was of particular interest to NDRF and was shortlisted for further Field Technology Showcases and analysis at the upcoming 5th Battalion field Technology Showcase. This product is designed to convert an Android smartphone into a Satellite Phone (wired or wirelessly).

    a. **Use-Case.** Off-the-shelf Satellite phones that are currently used by the NDRF are powerful, rugged, and dependable handheld devices that offer critical communication links when out of reach of terrestrial networks, no matter how remote or harsh the environment is. A cost-effective and scalable solution to increase numbers of satellite phones in the force is via the innovative approach to convert a regular smartphone to a satellite phone.

    b. **Technology[32].** The technology prototype developed by the innovator is a handheld, two-way, S-Band Satellite Mobile Radio terminal, designed to transform an Android phone into a Satellite Smartphone. The device supports voice, short messaging, geo location and narrow band data services in a compact form factor befitting any standard 5.5" Android Smartphone. Flexible to pair, it connects to any Android device over micro-USB (wired) or Wi-Fi/Bluetooth (wireless) mode.

    c. The wireless mode in the device can be configured as a satellite internet hotspot enabling exclusive satellite connectivity to multiple pre-approved Android Smartphones. In the absence of any terrestrial communication network, the device operates over ISRO's GSAT Satellite network, offering secured

[32] These details are specific to an innovator and are strictly illustrative of the technology

satellite communication to any other landline, cellular or sat-phone via a gateway installed at the hub-side.

3. However, due to the following reasons the innovator could not participate in the Field Technology Showcases and engage in discussions for usage of Satellite phones in the NDRF: Product development funds needed to customize the prototype to meet force (end-user) requirements and desired standards; Bandwidth/Spectrum allocation for NDRF has to be considered by ISRO post obtaining due clearances from Ministry.

4. **Private Wireless Networks.** After the Virtual Technology Showcase held on 10th Jan 2022, NDRF had shortlisted the Private 4G LTE Network for further evaluation and field trials. The product was tested in a robust and extensive Field Technology Showcase with the 5th Battalion of the NDRF, on the 10th and 11th May 2022 at Jadhavwadi Dam, Sudumbre, Pune. The Showcases were conducted based on Trial Scenarios, jointly conceptualized by the NDRF and AGNIi Mission. The process of testing the technology and evaluation has been laid out below.

Figure 28: *Private LTE Network at the Field Technology Showcase, 5BN NDRF Pune*

5. The Trial Scenario for Private LTE provided by NDRF was:

> *You have gone for a SAR operation to a deep gorge where a bus has fallen into a gorge, with 30 people on board. The communication facility is totally absent there and it is necessary to establish the communication with the Headquarter (NDRF HQ), BN HQ and among various SAR teams deployed at the site. You are directed to establish communication with the help of satellite phone and Private Network in a Box.*

6. The technology capabilities that were assessed through the showcase were:

    a. Establish communication within minimum time as disaster response is time critical;
    b. Range should be operationally sufficient: To be decided based on location and innovator personnel along with NDRF to exchange messages to test;
    c. Audio/Video communication through Push-To-Talk or any other mechanism possible.

7. The technology and its functional parameters were evaluated based on these broad parameters:

    a. Supported modes (voice, video)
    b. Backhaul options (Fiber/VSAT/ IP Radio)
    c. IP Radio Antenna frequency of operation
    d. Power Backup
    e. Operating Range (Line of Sight)

Figure 29: *Officers interacting with the innovator at the Field Technology Showcase, 5BN Pune*

Figure 30: *Private Wireless Network being showcased to NDRF officers, 5BN Pune*

8. Adoption Levers

The subsequent table in the section enumerates the five important attributes of innovation and how each was conveyed to the decision makers and technology adopters during the showcase of Private Wireless Networks:

	Adoption Lever	Technology / Operational Scenario Summary	How did the Showcase achieve this?
1	**Relative Advantage**	Private LTE Networks possesses a relative advantage over currently used satellite phones and QDA by offering improved user-friendliness due to integration with conventional smart phones, real-time data transfer and video calling option, exclusive spectrum for reduced network crowding and more scalable with multiple private LTE nodes that can form a mesh network.	The Showcase demonstrated relative advantage over the currently used equipment via the following indicators- ▪ Setup Time: Private LTE Network in a Box required a lesser setup and deployment time compared to QDA equipment. ▪ Data Rate: The bandwidth and data transfer rate in a Private LTE setup is significantly higher than QDA/VHF radio sets thus allowing for communication via video over voice and text.
2	**Complexity**	Private LTE networks require spectrum allocation, which can be challenging and complex to obtain in some cases. In addition, spectrum usage may need to be pre-coordinated with other communication systems to prevent interference.	The FTS adequately established the ease of set up and use of the equipment. The network in a 'box' aspect was made evident in its functioning, in that the only requirement to establish fast communication is the requirement of setting the equipment at a vantage point providing sufficient range. The FTS enabled this understanding of the minimal complexity to the Officers of the NDRF.
3	**Compatibility**	Compatibility with existing communication systems of the NDRF could be challenging. The existing systems include QDAs, Independent Sat Phones/Terminals by Inmarsat and BGAN as well as UHF/VHF Radio sets. The GSAT-6 based Satellite phone could operate independently while being compatible with other devices. However, the Private LTE Network in a Box may require additional customizations and trials to evaluate compatibility and pairing with existing systems.	The showcase did not demonstrate compatibility with existing communication systems. However, the compatibility of the technology with users (responders) was found to be positive. The FTS was able to establish the reduced complexity of usage. The technology trialed in Pune was a 20 kg machine, however it has manpack variants (10-12kg) that can be easily carried, reducing fatigue of the force personnel. Further, it requires little change in the operating procedures, minimal training and change in logistics.

	Adoption Lever	Technology / Operational Scenario Summary	How did the Showcase achieve this?
4	**Trialability**	The trialability of the Private LTE Network is high as it does not demand any major infrastructural and operational setup and spectrum permissions would not be required for trial purposes.	The Network in a Box lends itself to trialability by setting up an extensive range of communication. The technology was trialed by establishing communication with an NDRF jawan, situated at a distance of about 1km. The communication established was through a regular cellular phone, with the SIM card provided by the innovator. Video communication was instantaneously established between the Officers and the jawan.
5	**Observability**	The observability of the Private LTE network is high as its results, operational capability and performance can be observed and reviewed in real-time.	The video communication established by the network enabled a clearer observation of the relative advantage of the technology.

9. Performance Matrix

#	Feature Requirement	Description	Priority		Capability		Showcase Indication
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2			
1	**Redundancy**	The system should have redundant components and backup systems to ensure that it can continue to function even if one or more components fail.	Tactical Tier. *AC/Insp.* Priority Level: **High**	Operational Tier. *CO/2IC* Priority Level: **Medium**	**Multiple Antennas:** Using multiple antennas, also known as multiple-input multiple-output (MIMO) systems, is a common technique for redundancy in wireless communication.	**Multiple Frequencies:** Transmitting the same information over multiple frequencies, also known as frequency diversity, is another method of redundancy.	The Private LTE 4G Network in a Box showcased at the 5th BN Pune Field Technology Showcase allowed for - • 1.4,3, 5,10 and 20 MHz bandwidth support (Multiple Frequencies) • Number of Antenna 2T4R or 4T4R. (Multiple Antenna) • TDD/FDD mode based on Band of operation (Duplexing) • The eNodeB connects to 2x2 or 4x4 MIMO capable Omni / Directional antenna over RF cables (MIMO)
2	**Interoperability**	The system should be able to connect with other communication systems, both within and outside the affected area, to facilitate coordination and collaboration between response teams.	Strategic Tier. *DIG* Priority Level: **High**		**Software-Defined Radios (SDRs):** SDRs are radios that can be programmed to work with different communication protocols, for different systems and devices.	**Interoperability Gateways:** Devices that can translate between different communication protocols, allowing different devices to communicate with each other.	The showcase displayed - a. Voice call and video call between 2 subscribers within the private network.

#	Feature Requirement	Description	Priority		Capability		Showcase Indication
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2			
3	**Flexibility**	The system should be able to adapt quickly to changing conditions, such as power outages or network disruptions, and have alternative means of communication. It must also be easy to carry and port as and when the team is required to mobilize.	Tactical Tier. *AC/Insp.* Priority Level: **High**		**Mobile Networks** **Two-way Radios**	**Satellite Phones** **Mesh Networks**	The virtual, static, and field technology showcases displayed the below technologies and their flexible aspects useful for disaster response: • Private 4G LTE Network in a Box • Dual-Mode Satellite Phone and Terminal • Satellite based Location Tracker • Retro Upgraded Radio sets
4	**Resilient Power Supply**	The system should have a reliable power source that can operate independently of the local power grid, such as backup generators or solar power.	Tactical Tier. *AC/Insp.* Priority Level: **High**		**Backup Generators**	**Battery Backups** **Solar Power**	The showcase indicated the use of primary power from an external source for the Private 4G LTE Network, however, battery backup can be made available with external LiPo, as per need. The Satellite phones work on Li-Ion batteries and provide sufficient backup for extensive usage by personnel.

#	Feature Requirement	Description	Priority		Capability		Showcase Indication
			Adopter Decision-Making Tier 1	Adopter Decision-Making Tier 2			
5	**Multiple Channels**	Communication systems should support multiple channels of communication, including voice calls, text messaging, and data services.	Strategic Tier. *DG, IG* Priority Level: **High**	Operational Tier.*CO* Priority Level: **Medium**	**Voice communication:** It is useful for relaying critical information and coordinating emergency response efforts. **Video/Image Transfer:** Images and videos can depict a better picture of the on-ground situation.	**Text messaging:** Send short messages quickly and efficiently, which is particularly useful when phone lines are overloaded. **Social media:** Social media platforms can be used to quickly disseminate information during emergencies or disasters	The Satellite phones indicated voice communication whereas the Private LTE network devices could perform voice, video, and text communication during the showcase.
6	**Priority Access**	The system should have mechanisms in place to ensure that emergency responders and other critical personnel have priority access to the network during a disaster.	Operational Tier. *CO/2IC* Priority Level: **High**		**Preemptive access:** Method of prioritizing emergency comms by preempting non-emergency comms. **Quality of Service (QoS) prioritization:** Method of prioritizing emergency comms by assigning it a higher priority level than non-emergency comms.	**Dynamic spectrum sharing:** Method of prioritizing emergency comms by dynamically reallocating unused spectrum to emergency comms during a disaster. **Geofencing**: Method of prioritizing emergency comms by defining geographic areas where emergency communication will take priority over non-emergency comms.	During the showcase it was established that, the Private LTE Network in a Box supports 3GPP specified QoS Class Identifier which is a type of QoS prioritization.

PART E | WAY FORWARD | ASSESSMENT AND ADVISORY REMARKS

E.1 Summary

1. The National Disaster Response Force is critical in saving lives and restoring order in the aftermath of natural or human-made disasters. Personnel performance during disaster response is crucial to ensure successful outcomes. Three key ways to enhance and augment personnel performance during disaster response are through resilient communication, technical textiles, and load-assisting exoskeletons.

2. Resilient communication is vital during disaster response, as communication breakdowns can lead to chaos and even fatalities. Therefore, disaster response forces must have reliable communication systems that can withstand the harsh conditions of the disaster zone. These resilient communication systems can include satellite phones, handheld radios, and other advanced technologies that ensure clear and effective communication among team members. With resilient communication, disaster response personnel can coordinate their efforts, share critical information, and respond effectively to emerging challenges.

3. Technical textiles play a critical role in protecting disaster response personnel from the harsh environmental conditions they face during disaster response. Technical textiles can include flame-retardant clothing, protective gear, and other specialized fabrics that provide the necessary protection against extreme weather conditions, hazardous materials, and other dangers. By wearing technical textiles, disaster response personnel can focus on their tasks without worrying about their safety, thereby enhancing their performance and effectiveness during disaster response.

4. Load-assisting exoskeletons are advanced technological devices that can enhance the physical capabilities of disaster response personnel. These exoskeletons can help personnel lift heavy loads, move faster, and operate for extended periods without getting exhausted. By wearing load-assisting exoskeletons, disaster response personnel can conserve their energy and focus on the critical tasks at hand, thereby enhancing their performance during disaster response.

5. In conclusion, these technologies are critical tools that can enhance and augment personnel performance during disaster response. By investing in these advanced technologies and equipment, the NDRF can improve their effectiveness in responding to disasters, thereby saving lives and restoring order in affected communities.

E.2 Assessment and Advisory Matrix

1. An Assessment and Advisory Matrix is a tool used to evaluate the performance of a technology or solution in each context and provide recommendations for future use. This matrix considers various factors, such as the effectiveness of the technology in achieving its intended purpose, its suitability for use in different settings, and the qualifications and features required for optimal performance.

2. The matrix is designed to assist decision-makers in evaluating the technology's performance and potential impact, as well as identifying areas for improvement. It provides a systematic approach for evaluating the technology's effectiveness, based on a set of predefined criteria and benchmarks. In addition to assessing the technology's performance, the advisory aspect of the matrix provides guidance on its use in different scenarios. The matrix considers the specific needs and requirements of different contexts and provides recommendations on whether the technology is suitable for a particular use case.[33]

[33] This background applies to all the three Assessment and Advisory Matrices in this document

Self-Powered Exoskeletons

Strategic Context	Operational Scenario	Emerging Technology	Idealized Capability Requirement	Capabilities Indicated in Field Technology Showcase	Observations and Recommended Course of Action
High Uncertainty in Field Situations. Extended, continuous personnel functioning in time-contingent situations. Destroyed infrastructure environments.	1. Rescue operations involving debris clearance 2. Clearing pathways for NDRF vehicles, blocked by trees and boulders 3. Heavy equipment loading/unloading	Passive (Self-Powered) Load-Assisting Exoskeleton	-Increase weight-carrying capacity of the user -Avoid injuries to Musculoskeletal system -Reduce fatigue, strain and increase endurance, efficiency of wearer	The passive exoskeleton demonstrated at 11th BN Varanasi indicated the ease of operation, perceived weight reduction, extended upper body support, movement facilitation while carrying weights etc.	The Force may consider an initial procurement of a smaller number of exoskeletons for detailed and extensive usage, testing and for personnel to get accustomed and attain higher levels of comfort with the technology. This will also enable early feedback for customizations, design changes and product improvisation by the innovator. Technology demonstrates some key capabilities vis-à-vis requirement, at a high readiness and performance level. Others will require refinement and optimization, through collaborative consultation between Force and vendors. The Force may find it useful to integrate technology use into training exercises and SOPs. Also, it may try to institutionalize technology capabilities in operations planning / forming defensive grid / etc.

Technical Textiles

Strategic Context	Operational Scenario	Emerging Technology	Idealized Capability Requirement	Capabilities Indicated in Field Technology Showcase	Observations and Recommended Course of Action
High Uncertainty in Field Situations. Extended, continuous personnel functioning in time-contingent situations. Destroyed infrastructure environments.	The current NDRF apparel does not support high-tech properties such as water-resistance and enhanced breathability. The core material/textile used in the uniform are not adequate for moisture management and comfortability. Existing NDRF uniforms are plain viscose/polyester fabric which is uncomfortable during summers and low on colour fastness.	Technical Textiles	High Strength and Durability Flame Retardancy Water Resistance Breathability Chemical Resistance Anti-microbial and anti-bacterial properties Flexibility Comfort	Smart Temperature Anti-Microbial Durable Water repellent Breathable fabric Body odour resistant High abrasion resistance Air–dry capability	Technology is ready to be actively considered, through due process under competent authority. Meets adopter requirements. Functionally ready. The fabric had already been co-developed by the innovator and NDRF official's basis the parameters and requirements communicated.

Private Wireless Communications

Strategic Context	Operational Scenario	Emerging Technology	Idealized Capability Requirement	Capabilities Indicated in Field Technology Showcase	Observations and Recommended Course of Action
High Uncertainty in Field Situations. Extended, continuous personnel functioning in time-contingent situations. Destroyed infrastructure environments.	NDRF operated Inmarsat ISAT2 and BGAN for satellite communication is a private service, availed on subscription basis entailing hefty expenditure QDA operations requires multiple equipment (MODEM, VoIP Phone); current Ku band faces signal attenuation, especially during cyclonic conditions HF-VHF radio sets provide low data rates	Private Wireless Networks Dual-mode Satellite Phones Software-Defined Radios Upgraded Radio-sets	Form factor – Should be portable, modular, and quickly deployable. Power – high battery endurance, backup source. Redundancy – multiple frequencies, antennas, channels.	Private 4G LTE Network in a Box - Quick setup and deployment, minimum operating infrastructure, Video/Voice calls, Line of Sight communication were the capabilities indicated in the Field Technology Showcase	The Force may consider extended trials that involve testing all aspects of the technology at field locations. Once the technology is found to be suited for communication during disaster scenarios in terms of user-comfort, robustness, scalability etc., NDRF may move towards next steps of spectrum allocation, customizations for force-specific needs and interoperability with current comms equipment. Private 4G LTE Network in a Box demonstrates some key capabilities vis-à-vis the requirements, at a high readiness and performance level. Others will require refinement and optimization, through collaborative consultation between Force and innovators. The FTS helped uncover critical issues around Spectrum allocation. NDRF would need to enable the innovator to acquire spectrum for regular usage. The demonstration at the NDRF site did not require spectrum allocation. Once procured for real-world usage, the spectrum allocation needs to be approved by the Dept. of Telecom as well as obtained and operated at a force level for designated comms and minimal interference. The Force may find it useful to integrate technology use into training exercises and SOPs. Also, it may consider

Strategic Context	Operational Scenario	Emerging Technology	Idealized Capability Requirement	Capabilities Indicated in Field Technology Showcase	Observations and Recommended Course of Action
					institutionalizing technology capabilities in operations planning / forming defensive grid / etc. Further, the spectrum allocation issue be taken up in consultation with the innovators to ensure that by the time the Force receives the final products, they are readily deployable. Currently, the technology does not provide backhaul: that is, it does not connect with the existing telecom infrastructure. However, this may be useful for the Force as observed by the DIG (Prov.). However, most other end users who are procuring network in a box are doing it precisely to have a separate, private network. Therefore, the flexibility to operate in the commercial spectrum bands as well may require Department of Telecom approval along with technological changes. If after the prolonged trials, the Force finds the technology viable, it may consider Advanced Market Commitments to incentivise the innovator to make the necessary customizations.

Office of the Principal Scientific Adviser
to the Government of India

The AGNIi Mission
Office of the Principal Scientific Adviser to Government of India
Vigyan Bhavan Annexe, Maulana Azad Road, Delhi 110011

www.agnii.gov.in