Office of the Principal Scientific Adviser
to the Government of India

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agnii IGNITING IDEAS

Unmanned Systems for Hostile Environments

Technology Advisory Note

Unmanned Systems for Hostile Environments

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

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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 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 organizational 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

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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 (TAN) focuses on how **emerging technology and innovation** – capabilities for which exist in **India's innovation ecosystems**, start-up, and laboratory – can **act as a force multiplier 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, applies more widely to infantry across the Central Forces. This innovation includes Unmanned Systems comprising of Rescue Buoys, Surveillance and Payload Drones, Autonomous Boats, Underwater Submersibles to enhance capability – their decision-making, capacity and response time.

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 startup 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 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, startup, innovator, or private actor of any kind. The TAN features specific technologies – whose innovator startups 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?

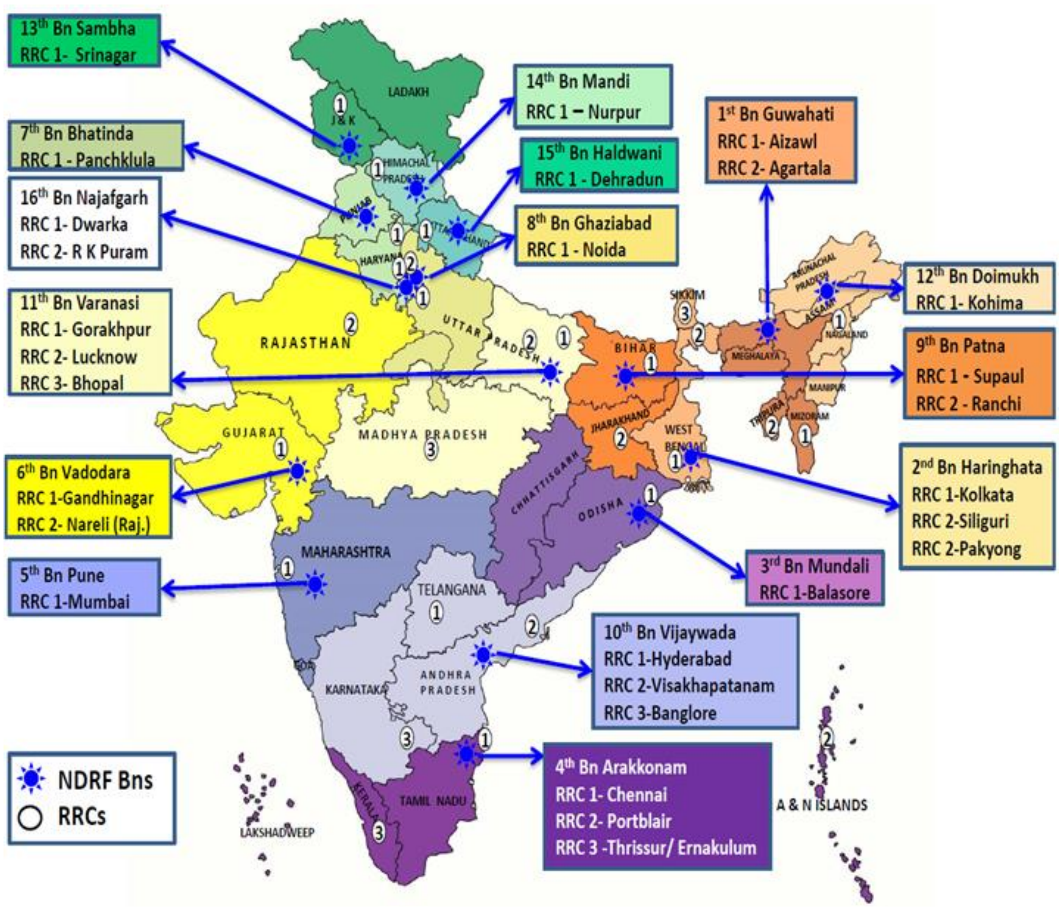


Figure 1: *Map showing NDRF Battalion locations and their respective area of responsibility*[2]

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 emergencies (CBRN)[3].

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

2. As per Section 3.4.5 of National Policy on Disaster Management 2009, the State Governments are required to raise their own State Disaster Response Forces (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 AGNIi identifies with the NDRF, with individual State Forces emulating the national tier agency to boost capability. This institutional scaling would be catalyzed by organizational 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 unmanned systems in unpredictable environments such as disaster sites and challenging terrains therefore addresses a pool of approximately **26,000 personnel.**

5. Crucially: the main focus areas of the TAN – leveraging unmanned systems in hostile environments for enhanced intelligence leading to improvised response on the ground against adversaries– applies across multiple Central Forces. This applies to up to six Forces, comprising approximately **8.4 lakh personnel** (please see below).

		BSF 2,65,277	17,235	94,358	CISF 1,63,498	3,24,654	SSB 97,790	88,430	65,143	NSG 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*

[4] National Disaster Management Authority, Government of India. *State Disaster Response Force.* https://ndma.gov.in/Response/SDRF

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

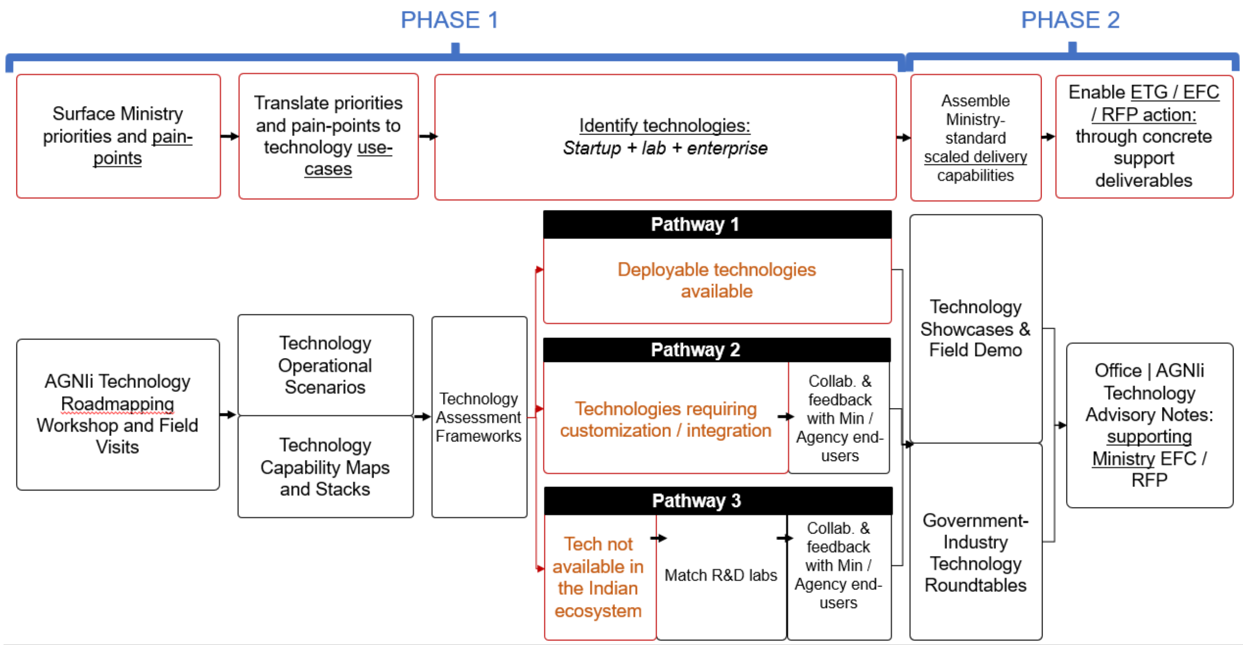


Figure 3: *Office of PSA | AGNIi Workflow*

1. **Practicality: Ensuring Technology Decision-Making Support is <u>Actionable</u>.** To ensure that agency decision-makers receive technology and innovation advice that is **<u>actionable in the field</u>**: the Office's AGNIi Mission, under the Prime Minister's Science Technology and Innovation Advisory Council (PM-STIAC) 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 <u>scaled impact</u> against these priorities to be assured by the emulation and adaptation of Pioneer Agencies' examples.

2. **Ensuring <u>Decision-Making Relevance</u>: Technology Operational Scenarios.** AGNIi targets emerging technology innovation to <u>support agency priorities and requirements</u>, 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. Pioneering Agency, one which deals with the '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): 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.

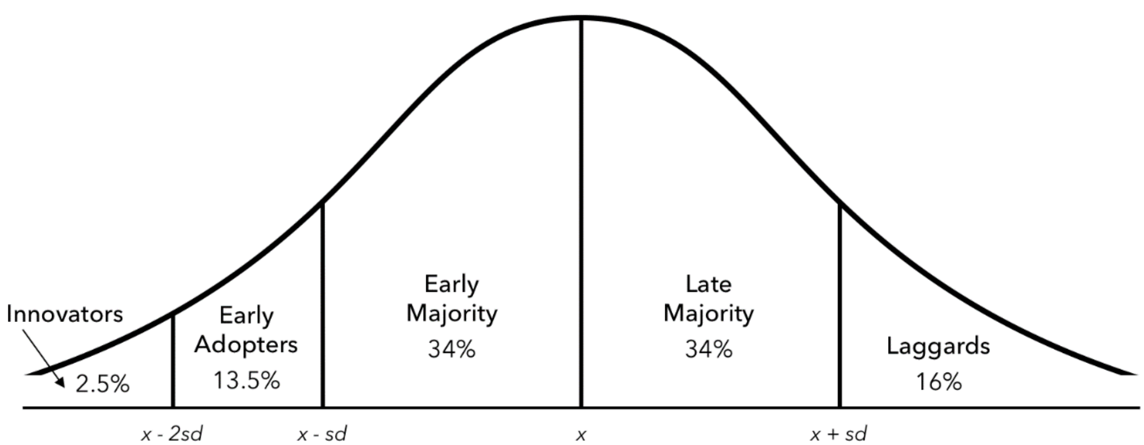


***Figure 4:** Relationship between types of adopters classified by innovativeness and their location on the adoption curve*[5]

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

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.

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; 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 Head Quarter (HQ) guidance): describing baseline scenarios and target end-state. Develop Technology Stacks: reflecting functional requirements generated by Operational Scenarios. Collaborate with Frontier HQ and field implement Field Technology Showcases: demonstrating how Indian innovation work (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 TAN
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	TAN

PART B | STRATEGIC CONTEXT | PROBLEMS AND CHALLENGES

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

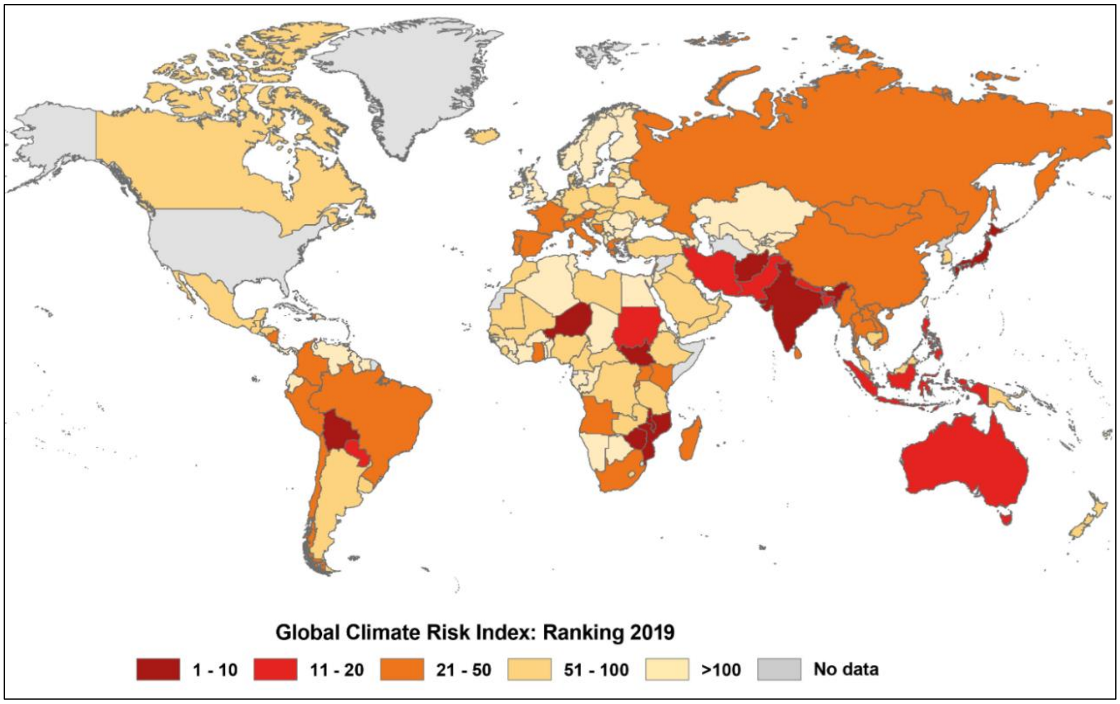


Figure 5: *Global Climate Risk Index 2019: India was 7th most impacted due to extreme weather events in 2019*

1. This TAN outlines how emerging technology and innovation – capabilities of which exist in India – can **act as a force multiplier for Central Forces personnel in environmentally-hostile, field situations** for the NDRF, and State Disaster Response Forces, during 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[6]. 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 an exacerbating these hazards, increasing vulnerabilities of the country[7]. India is the **seventh most impacted country due**

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

to extreme events caused by climate change[8]. The Government of India passed the Disaster Management Act in 2005 to provide 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 7 lakh stranded persons** from disaster situations within the country and abroad, that include successful rescue operations in Japan (2011), Nepal (2015) and Turkey (2023).[9]

4. The National Disaster Response Force has been 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, National Disaster Response Force consist 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 49 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 natural as well as man-made disasters. Battalions are also trained and equipped for response during 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.

[8] David Eckstein, Vera Kunzel, Laura Schafer, '*Global Climate Risk Index 2021*', Germanwatch;

[9] Ministry of Home Affairs, Government of India. National Disaster Response Force. *DG's Message.* www.ndrf.gov.in

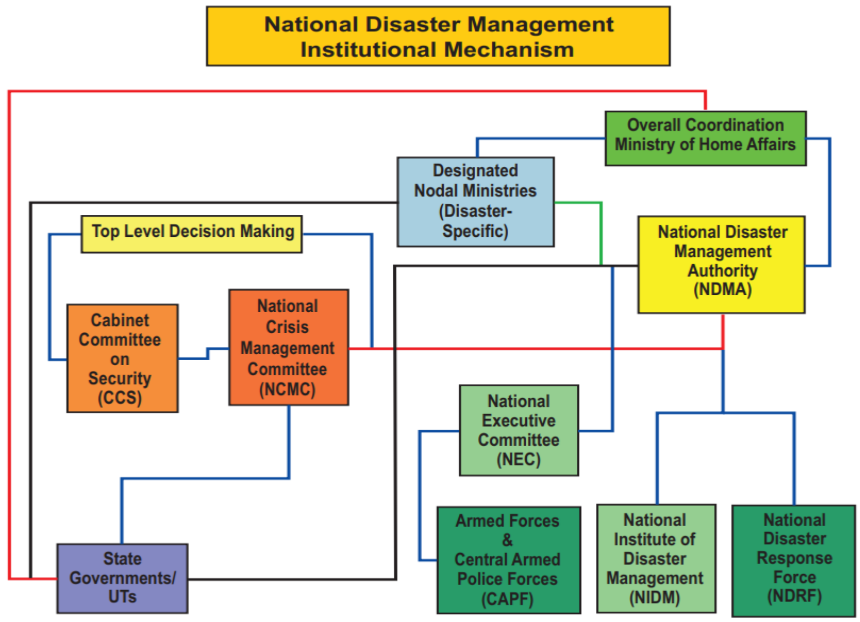


Figure 6: *National Disaster Management Institutional Framework*[10]

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

   a. As per the DM 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.

[10] Source: National Disaster Management Plan 2016

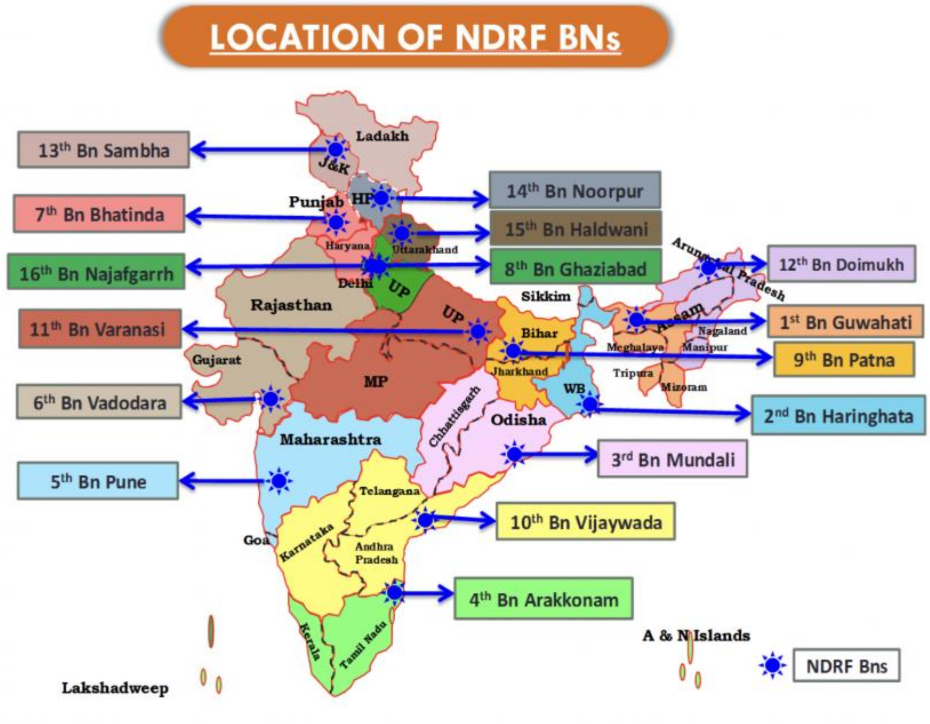


Figure 7: *Map indicating locations of all NDRF Battalions in India*[1]

7. NDRF battalions are located at 16 different locations in the country based on the vulnerability profile of country (Figure 7).

8. In this context, unmanned technological systems that can operate independently or assist rescue teams in hazardous and high-risk environments are a vital need for Search and Rescue (SAR) operations.

9. 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 recover from loss. The disaster management cycle has been illustrated on the next page.

Figure 8: *Disaster Management Cycle – Mitigation, Preparedness and Response*[1]

10. The mandate of NDRF restricts it to <u>Response and Relief operations</u> only. As such, the technological interventions must be geared towards enhancing personnel performance in this domain.

11. **<u>Strategic Context</u>: High Uncertainty in Field Situations.** A key element in Force responses to disasters and high-pressure field situations is <u>uncertainty</u>. Personnel are placed in circumstances that cannot be predicted, which involve:

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

    b. <u>Time-sensitive, complex operations</u> in hostile environments; characterised by destroyed infrastructure in post-disaster scenarios:

        i. Victim rescue from collapsed structures, flooded areas, all of which impose hard constraints on accessibility. Search and Rescue needs to be informed by these limitations going in;

        ii. Inability to obtain real time intelligence and inputs that enable a common operating picture.

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 in India, affected states, fatality count for the last 20 years*[11]

[11] Source: National Disaster Management Authority (NDMA), Centre for Research of Epidemiology of Disasters

12. **Technology Stack Design Imperative: Operating Unmanned Systems in Environmentally Hostile Situations.** The effectiveness of rescue and relief is directly proportional to the situational awareness achieved as well as supplemented capability of Search and Rescue teams before the start of an operation. This has **implications for technology use-case definition** and **shapes the Technology Stack**.

Strategic Factor	Functional Implication	Technological Response: Consequences for Technology Stack Composition
Extended, continuous personnel deployments Destroyed infrastructure environments. Time-Sensitive Complex Operations	Greater Situational Awareness and Enhanced capability in responder teams	Human factor: - Better Decision Making - Greater Operational Coverage and Reach - Faster Turnaround Time with Versatility

B.2 Use-cases, Pain-Points, Operational Scenarios and Functional Requirements

The Group Security of the AGNIi Mission was tasked with several problem statements by its primary stakeholder, the NDRF, that involved the usage of Unmanned Systems for a faster, efficient, and robust response. The use-cases that were prioritized, evaluated, and chosen for Field Technology Showcases have been described below.

1. Wide-area Recce and Surveillance at Disaster Sites: Unmanned Aerial Vehicles for aerial surveillance of disaster struck areas (landslides, floods, cyclones etc.) capable of real-time relay of video feed to rescue team and command and control center; Must have high gust resistance, weather tolerance and hover stability. Semi-autonomous, remotely operated with obstacle avoidance capabilities.

2. Internal Surveillance for Collapsed Structure Search and Rescue (CSSR): Compact UAV to traverse inside collapsed structures for locating victims/survivors and debris fracture zones with live video feed relayed on operator's First Person View (FPV) googles; Strong Radio Frequency (RF) to penetrate through walls, small form factor for high maneuverability; manually operated to avoid false obstacle avoidance.

3. Payload drop for emergency relief aid during disasters: UAVs capable of carrying and drop/deliver custom payload comprising of emergency relief aid (medicines, food, water packets) to designated coordinates for ensuring survivability of victims. Capable of dynamic landing, winch-based payload drop mechanism.

4. Rescue Lifebuoy for Drowning Victim Response: Unmanned remotely operated lifebuoy for drowning victim rescue operations; faster action time compared to manned rescue boats; capable of navigating back to shore with victim.

5. Underwater Scanning for Inspection and Recce: Underwater Remotely Operated Vehicle (ROV) for identifying victim bodies, objects of interest, debris etc. in murky/unclear waters using combination of dehazing on live video feed, side scan SONAR and imaging SONAR.

Pain Point	Use-Case	Operational Scenarios	Functional Requirements
Paltry and patchy information of a disaster/area of responsibility Search and Rescue may take time, citizens may require urgent medical relief Inaccessibility of localities due to collapse of infrastructure/earth movement (landslide, mudflow), floods.	Drone-based Surveillance and Response during Disasters	Aerial recce during and post disaster is critical for enhancing situational awareness of responder teams to assess damage and destruction, chart out rescue and response and locate victims and survivors from vantage points. During landslides, floods, earthquakes, and cyclones, most zones are inaccessible due to damage to infrastructure and inclement weather. Rescue troopers need unmanned systems to perform early analysis of disaster zone to improve response time and efficiency. During CSSR operations, responders require an internal investigation of collapsed site to identify fracture zones, trapped victim points, debris sites etc. to minimize further damage and rescue stuck victims in a timely manner. Situations where rescue of victims is a longer process and requires support from multiple stakeholders, temporary arrangements for medicines, food, water and other relief material need to be made in disaster-struck areas that are hard-to-reach and severely affected. Systems capable of delivering emergency relief aid to survivors, without the need of human on-board to reduce further risk, will be critical to ensure survivability until complete rescue concludes.	**Specific** Wide-Area Surveillance -Endurance of 45-60 mins -Operational range of 5-15 Kms -Wind Resistance up to 40km/hr -Red, Green Blue (RGB) Day/Night Camera payload Internal Surveillance -Small form factor for tight spaces -Uninterrupted radio frequency and video link -Front and downward facing cameras for live feed Payload Drop and Delivery -Payload capacity: 5 to 10 kgs -Stability for gust resistance -Winch/chute payload drop **Generic** -Pre-programmable flight paths -Fail safe - Return to Base -Detect-and-Avoid capability for beyond visual line of sight flights -Design: Multi Rotor or Hybrid vertical take-off and landing drones preferred over fixed wing configurations as they enable higher payload capacities, better stability and ability to hover -Interchangeable and modular payload containers having different size and shape based on requirement -Power: Gasoline-powered UAVs are preferred over battery-driven ones due to better endurance and wider availability of fuel with responder teams

Pain Point	Use-Case	Operational Scenarios	Functional Requirements
Flash floods/Urban floods have strong currents and debris that may prevent movement of larger boats; Number of rescue teams are limited and may suffer fatigue; Mapping of new water bodies under time constraints is currently not possible; human divers have limited vision, constraints of oxygen cylinders and stamina.	Floodwater Rescue and Response	In water bodies with strong flow and currents (rivers, streams, dam water etc.), victims caught in the current are unable to gain control and succumb to drowning within a few minutes. An unmanned buoy must reach the victim within 1-2 minutes, must adequately deal with frantic movements of victim without capsizing, design must be able to help victim grab onto right points of buoy, must navigate and bring back the victim safely to shore/nearest responder. In zones critically affected by floods, large accumulations of water require long hours of traversal via crewed rescue boats to rescue victims that are stranded or stuck. In operations involving underwater recce and rescue, trained and experienced divers are needed to go deep into the water body and locate dead bodies, debris or any object of interest. This exposes divers to risk, consumes more time as manual surveillance will cover less area and is near impossible when waters are murky and unclear. Tethered remotely operated vehicle capable of scanning underwater and operating in tandem with manned boats will be a differentiator during such operations.	Rescue Buoy -Remotely Operated, range~2km -Self-righting design -Weight pulling capacity ~100kg -High thrust motors Unmanned Marine Surface Vessel -Autonomous Navigation -Self-righting design -Weight pulling capacity ~6 adults -Cameras and Sensors for real-time video feed Underwater ROV -Omnidirectional Movement -SONAR for Underwater Imaging in murky waters -Operating Depth ~100m

6. **User Persona Mapping**

a. The User-Persona table seeks to structure the argument for technological intervention by initiating a role-responsibility mapping. The roles and responsibilities of each position in the state hierarchy are well defined. Understanding these roles and responsibilities is key in shaping decision making by contextualizing technological interventions within these ranks, roles, and their interests.

b. The User Persona Mapping is followed by a Need Feature mapping, wherein the needs of the two relevant tiers are matched with features of technologies that help address those needs. The features are critical in making the broader case for scaled impact. While the exemplar site and the pain points and operational scenarios arising out of it were made based on visits to the location and interaction with officers and hence based on qualitative evidence, the potential and need of scaled intervention by other similarly situated officers, facing a similar problem is made based on the Need-Feature mapping. The needs of strategic and operational tiers are brought out in the table and the features of the technology that can address this generalised need are mapped.

c. In this manner, the Field Technology Showcase and the advisory arising out of it seeks to ensure that the recommendations are within the scope of jurisdiction and authorization environment of the officers concerned.

Decision-Making Tier	**Deputy Inspector General (Ops) and Deputy Inspector General (Prov)**	**Commandant/2IC (Commanding Officer of the Battalion)**	**Inspector /Assistant Commandant (Team Commander)**
Role and Key Priorities	NDRF is a small force dedicated towards disaster response across the country. The DIG's in-charge of the vertical at the HQs are required to define and design the strategy along with coordination amongst the various units.	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 engineers, technicians, electricians, dog squads and medical/paramedics. The total strength of each battalion is 1,149.	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-charge of community awareness program to improve disaster preparedness, imparting training regarding life saving methods like medical first responder, rope rescue technics, CBRN response.

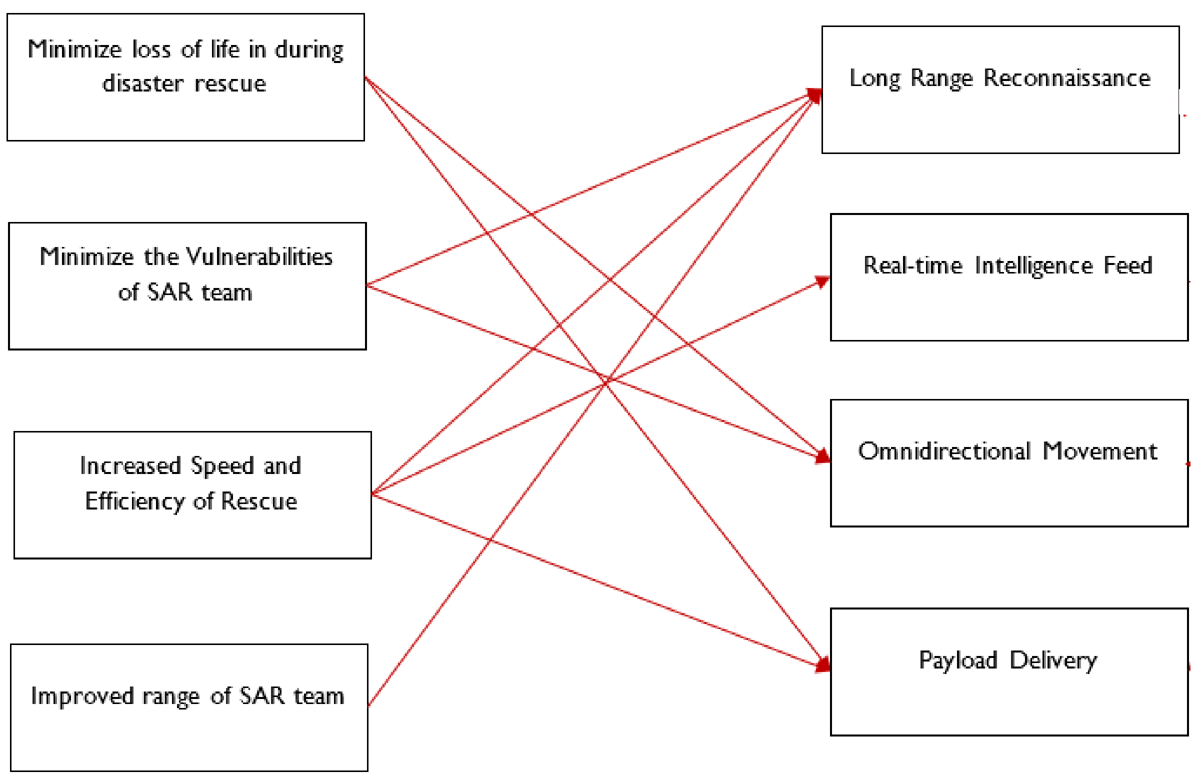
Background	DIG Ops is in-charge of the operational deployment along with strategy to be implemented on ground of the complete 16 battalions of the force. DIG Prov is in-charge of procurement of arms, ammunition, vehicles, clothing, equipment, furniture and other miscellaneous stores. In addition to the 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 subordinates such as Company Commanders and Staff Officers -Maintain a high level of operational Readiness within the Battalion -Provide tough, realistic training -Enforce NDRF Standards to 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 Incident Command Post (ICP) at the site.

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 Structure Search and Rescue (CSSR), Flood Water Rescue (FWR), and CBRN operations. Enhancing the personnel performance while ensuring their safety is the priority along with getting superior ground level intelligence.	-Commandant views the technology from user perspective with respect to 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 during chemical, biological, radiological and nuclear (CBRN) emergencies as well.	-His/her interests are the safe and quick response to the incident while simultaneously following orders from the hierarchy above him/her. -Interest lies at the cross section of speed and innovation, whether process or product, to improve response and create a sense of calm at the disaster site.
Behavior and Decision Triggers	Deployment of the technologies ought to be scalable, maintenance, repair is the focus, cost effective, easy to integrate, user 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.
Functional Requirements from Technology (Unmanned Systems)	DIG (Ops) - Real-time monitoring of Disaster situation and resolving dynamic requirements arising in team deployment and inter-agency coordination. DIG (Prov)- understanding equipment utilization and requirements	-Comdt./2IC – Smooth liaison and interfacing with State govt. and district authorities, SDRF and local relief workers to share real-time updates and information for faster response.	-Team Commander/ SAR Team -Tech to augment team's capacity during operations, perform in high-risk environments, elevate on-ground intelligence of responders for faster action.

7. **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.



PART C | TECHNOLOGY | FEATURES, CAPABILITIES AND STACKS

C.1 Background – The Need for Unmanned Systems

With advancements in technology adoption and associated complexity in tasks or operations involving higher degrees of risk and precision with relatively shorter execution time, systems capable of performing operations without the physical presence of a human are proving to be the first choice. Better known as Unmanned Systems, these can either be remotely operated by humans or can be semi/fully autonomous.

I. Need: A Systems Perspective[12]

1. Unmanned systems have significant advantages over manned systems. The absence of any human onboard makes these systems well-suited for monotonous and tedious (repetitive, long hours) duties as well as dangerous (hostile, high risk) and hazardous CBRN environments. Additionally, it permits the design to be optimized for very high performance, unconstrained by physiological limitations, especially the 'g' forces that manoeuvring in three dimensions involves.

2. The need for life support systems, specifically for aerial and underwater systems, such as air conditioning and personal oxygen systems, cockpit escape systems and transparent canopies is obviated. The small size, modest weight, low Radar Cross Section (RCS), low acoustic signals and high-altitude envelopes are other operational benefits of UAV. Crash survivability features are far less rigorous as they need to cater only to onboard systems and not to comparatively delicate humans. In fact, there is no need for a cockpit rendering the airframe design more stealthy and agile.

3. All these eliminated features offer a favourable trade-off in terms of additional payload by way of fuel/batteries, communications, cameras, sensors or weapons systems. The absence of a human onboard also means the design can look at protracted endurance as fatigue, sleep and rest requirements, short- and long-term consequences of sitting for too long in one posture, do not restrain the duration of missions. The cost factor is another persuasive argument in favour of unmanned systems as it is considerably lower than comparable manned alternates. An operational benefit accruing from the lower cost is that their loss can be risked more incautiously, and hull losses accepted more casually.

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[12] Sachdev, AK. *The need for Unmanned Aerial Vehicles for the IAF*. Issue Vol. 37.3, Jul-Sep 2022. 20 Oct 2022. http://www.indiandefencereview.com/news/the-need-for-unmanned-aerial-vehicles-for-the-iaf/

II. Need: A Mission Perspective

1. In situations of confrontation, conflict, and hostility - unmanned systems have proven to be a force multiplier by:
    a. enhancing the real-time situational awareness of patrol troops on the border and emergency first responders during a disaster;
    b. supporting logistical and food/medical aid requirements at inaccessible areas and disaster struck zones via payload drop;
    c. rescuing drowning victims and locating drowned bodies and property underwater.

2. In all the above situations, unmanned systems can operate and deliver with greater versatility, faster turnaround time while expending lesser costs thus resulting in greater efficiency and higher operational standards.

C.2 Unmanned Systems – An Explainer

1. An Unmanned System (US) or Vehicle (UV) can be defined as an "electro-mechanical system, with no human operator aboard, that is able to exert its power to perform designed missions"[13].

2. UVs can be remote controlled (by a remote pilot) or can navigate autonomously based on pre-programmed plans or more complex dynamic automation systems. They include vehicles moving in the air (Unmanned Aerial Vehicle or System—UAV, UAS, commonly known as "drone"), on the ground (Unmanned Ground Vehicle—UGV), at the sea surface (Unmanned Surface Vehicles—USV) or in the water column (Unmanned Underwater Vehicles—UUV).

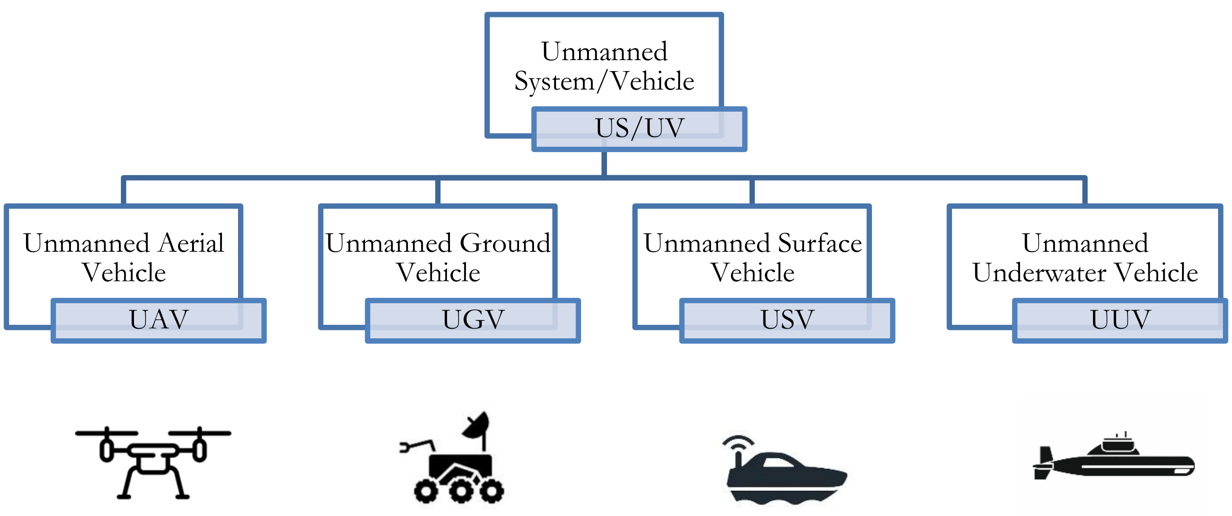

***Figure 10**: Categorization of Unmanned Systems based on medium of operation*

[13] Huang, H. National Institute of Standards and Technology. *Autonomy Levels for Unmanned Systems*. (ALFUS) Framework. Volume I: Terminology. Version 2.0. October 2008. https://www.nist.gov/system/files/documents/el/isd/ks/NISTSP_1011-I-2-0.pdf

3. **Unmanned Aerial Vehicles (UAV).** UAVs, also called drones, are unmanned systems navigating in the air, able to survey wide areas, and are able to reach human-hostile environments, too. They can be remotely piloted or autonomously controlled. There exist different types of UAVs, depending on the specific purpose the UAV is designed for. UAVs can differ in size from the order of centimetres to tens of meters, in weight from tens of grams to thousands of kilograms, in operational altitude from tens of meters to thirty kilometres, and in range from 100 m to 1,000 km.

    a. Based on the application, UAVs can have different designs – Rotor-based, Fixed-Wing and Hybrid VTOL (Vertical Take-Off and Landing). Multi-rotor UAVs are the most commonly used due to its small size, easy control and higher stability. Fixed-wing options are preferred for tasks requiring longer endurance and low aural signatures.

    b. UAV-related technology is continuously and rapidly evolving, and the number of applications for UAVs is growing exponentially, and includes real-time monitoring, providing wireless coverage, remote sensing, search and rescue, package delivery, security and surveillance, precision agriculture, and civil infrastructure inspection.

4. **Unmanned Ground Vehicles (UGV)[14].**UGVs are unmanned systems operating on the ground. They are used for many applications including space exploration, environment sensing, logistics, industrial automation and search and rescue, and can have many different configurations, usually defined by the task they must perform, as well as the environment in which they must operate. UGVs have been developed in different sizes (varying from 500 g to 25,000 kg) and configurations, typically linked to the mission they were designed to carry out.

5. UGVs are generally equipped with a controller and on-board sensors to observe the environment and make decisions autonomously or send the information remotely to a human operator. Since UGVs' on-board sensors cannot see what is beyond obstacles around them, these kinds of unmanned vehicle can be impeded by their reliance on line-of-sight sensing. Environmental perception and level of autonomy are the main characteristics being focused on with respect to current and future technological developments for Unmanned Ground Vehicles.

6. **Unmanned Surface Vehicles (USV)[15].** USVs are vessels operating on the surface of water and can be remotely operated or autonomous. USVs can be realized in many different forms, depending on the specific application. They can vary in weight from tens of kg to thousands of kg, with speeds that can vary from 1 m/s-20 m/s. USVs can operate in conditions that are dangerous and risky for human safety. Moreover, this kind of vehicle is compact, and has low maintenance costs.

7. Although USVs were initially used in typically naval applications, such as, for example, surveillance and reconnaissance, nowadays they are also widely used in civil applications, such as environmental monitoring and assessment, autonomous shipping, search and rescue, offshore surveying in the oil and gas industries, seabed mapping, and inspection of structures above and below water.

[14] Balestrieri E, Daponte P, De Vito L, Lamonaca F. Sensors and Measurements for Unmanned Systems: An Overview. *Sensors*. 2021; 21(4):1518. https://doi.org/10.3390/s21041518
[15] ibid

8. **Unmanned Underwater Vehicles (UUV)[16].** UUVs operate under the surface of the water with minimal or no human operator intervention. UUVs can be of different types, varying in shape and size, depth ratings, payload, navigational capabilities, and control. UUVs can differ in length from little more than one meter to tens of meters, can operate at different depths varying from 200 to 6,000 m, and at different speeds from about 0.5 to 4 m/s, with a weight of up to thousands of kgs.

9. These vehicles can be ROVs, controlled by a remote operator, or Autonomous Underwater Vehicles (AUVs), operating independently from direct human input. AUVs are the most complex, having to rely on autonomous functions in a difficult environment such as the aquatic one. UUV applications include persistent surveillance, anti-submarine warfare, underwater construction and infrastructure maintenance support, oceanography, hydrography and mine countermeasures.

C.3 Technology Stack

1. Unmanned systems are robotic machines that operate without human intervention or with limited human control. They can be used in various fields such as military, agriculture, mining, surveying, and many more. The following are the key technological features and components of an unmanned system:

    a. **Sensors:** Sensors are critical components of unmanned systems that provide the machine with situational awareness. Sensors can include cameras, Light Detection and Ranging (LIDAR), Radio Detection and Ranging (RADAR), Global Positioning System (GPS), and other specialized sensors that allow the unmanned system to detect obstacles, identify objects, and measure environmental conditions.

    b. **Control systems:** Control systems are the 'brains' of an unmanned system. They are responsible for processing sensor data, making decisions, and controlling the machine's movement. Control systems can range from simple microcontrollers to sophisticated software that uses artificial intelligence and machine learning algorithms.

    c. **Communication systems:** Communication systems are used to transmit data between the unmanned system and the operator or other machines. Communication systems can use various technologies such as radio, satellite, and cellular networks.

    d. **Power systems**: Power systems are the source of energy for unmanned systems. They can be powered by batteries, fuel cells, or other energy sources, depending on the application.

    e. **Actuators:** Actuators are the components that convert electrical or pneumatic signals into mechanical motion. They can include motors, servos, and hydraulic or pneumatic cylinders.

[16] ibid

f. **Navigation systems:** Navigation systems allow unmanned systems to determine their location and orientation. They can include GPS, inertial sensors, and other positioning technologies.

g. **Payloads:** Payloads are the equipment or sensors that are carried by an unmanned system. They can include cameras, sensors, weapons, or other specialized equipment.

2. Overall, unmanned systems are complex machines that require advanced technology to operate. By integrating these technological features and components, unmanned systems can perform a wide range of tasks with high efficiency and precision.

3. The technology stack on the next page highlights the critical components of each element: Design, Perception, Autonomy and Power of an Unmanned System operating across different mediums (air, ground, water).

Medium / **Element**	**Aerial (UAV)**	**Ground (UGV)**	**Water**	
			Surface (USV)	**Underwater (UUV)**
Design	- Multi-Rotor - Fixed-Wing - Hybrid VTOL - Flapping-Wing	- Wheeled and Tracked - Variable Geometry	- Monohull - Twin-Hull Catamaran Small Waterplane Area Twin Hull	-Open/Box Frame -Torpedo shaped -Tethered/Untethered
Perception	Position, Orientation and Navigation: Inertial Measurement Unit (IMU), Global Navigation Satellite System (GNSS), Accelerometers, Gyroscopes, Tilt sensors Sensing and Imaging: RGB, EO-IR/Thermal Cameras, Multi & Hyperspectral Cameras, LiDAR, RADAR (SAR), CBRNE	Proprioceptive: GNSS and INS Exteroceptive: EO-IR & Ultrasonic sensors, LiDAR, RADAR (GPR), Explosive/Gas detectors, LADAR Rangefinders; Stereo, Monocular, Omnidirectional, Event Cameras	Position, Orientation and Navigation: IMU, GNSS, Accelerometers, Gyroscopes, Tilt sensors Sensing and Imaging: Visual & Thermal-IR Cameras, SONAR, LiDAR, RADAR	Position, Orientation and Navigation: Inertial Systems, Long Base Line/Short Base Line/Ultra Short Base Line Acoustic transponders, Pressure sensors for depth Sensing and Imaging: Optical Light sensor and Cameras, Multibeam Echosounder and Side Scan SONAR

Medium	Aerial (UAV)	Ground (UGV)	Water	
Element			Surface (USV)	Underwater (UUV)
Autonomy	- Computer Vision on camera feed - Waypoint-based navigation via GPS - Artificial Intelligence over on-board flight and sensor data - Obstacle detection and Collision avoidance	- Autonomous Navigation: Geo-localisation, Path Planning - Camera + Sensors: Depth perception, obstacle avoidance, 3D maps	-Path Planning and obstacle avoidance for multi-vessel encounter via Velocity Obstacle (VO) algorithm	- Sensor fusion for autonomous navigation and ocean mapping - Dead reckoning approach via Inertial navigation combined with underwater acoustic, geophysical and optical positioning systems
Power	- Gasoline powered - Electric Powered (Li-Po and Li-ion batteries)	-Battery powered (Lead-Acid, Li-Po) -Fuel-Cell & Battery (Hybrid)	-Battery Powered (Li-ion or Valve Regulated Lead Acid)	- Battery Powered (Li-ion, Li-Po, Nickel metal hydride)

4. **Prioritization Matrix**

The need for technological intervention is of utmost importance for successful implementation of unmanned Systems. On the basis of the above-mentioned need-feature mapping and technology stack, technological capabilities that have the capacity to address the needs, and their relevance to the end-user are mapped in the following matrix. The various layers of the matrix are:

a. Feature and its description
b. Technological capabilities and the specific layers that have the said features
c. Relevance for the end adopter

#	Feature	Description	Capabilities				Relevance for Strategic tier	Relevance for Operational tier
			Autonomy, endurance, long-range connectivity	Payload delivery	Perception	Form Factor		
1	**Long Range Reconnaissance**	Unmanned systems provide the deployed force with the capability of long-range surveillance;	Long range connectivity and autonomy enable BVLOS[17] operations; autonomous functioning can enable preprogrammed flight paths;	Payload will need to be adjusted to optimize endurance;	Long range cameras can enable better informed SAR;		DG, IG – Early understanding of disaster impact	DIG, CO – Better planning of deployment

[17] Beyond Visual Line of Sight

2	**Real time intelligence feed**	Unmanned systems enable formation of common operating picture for the force deployed. This is achieved by increasing range, imaging capabilities that older platforms may lack, ability to reach confined places like collapsed structures;	Endurance and autonomy enable better inputs: Set paths can act as survey of disaster struck areas, endurance enable on-the-go identification of stranded victims; it can provide improved and sustained intelligence and monitoring of an area;	Images obtained by day cameras can provide the larger deployment with a bird's eye view;	Sensing payloads (day camera, LiDAR, SONAR) can help obtain situational awareness, 3D terrain mapping enabling a profound change in nature of information about rescue operations;		DG, IG – Live assessment of damage and support needed	DIG, CO – To understand troop and equipment coverage, reinforcements
3	**Agile Movement**	Unmanned systems can be put through riskier terrains and environments as they do not risk life of operator. This may entail collapsed structures, flooded areas, forest fires amongst others;	Movements of the unmanned system needs to be quick. It is required to have sufficient freedom to change track to avoid collisions in confined spaces;	Payload will need to be adjusted to optimize agility;		Depending on the exact requirement, the unmanned system can be small (nano drone) for maneuvering through confined spaces, shaped to cut through choppy waters (USV), designed to withstand stronger wind conditions;	DG, IG – Ensuring safety of personnel	DIG, CO – Ensuring battalion and SAR team efficiency

4	**Load Delivery**	Most unmanned systems are a platform to carry a payload: This diversity can be exploited by using them to drop relief material, cameras for imaging etc.	Long endurance can be coupled with payload delivery for providing relief materials.		DG, IG – Assess quantum and type of relief material needed	DIG, CO – Decide immediacy of relief and locations

PART D | DEMONSTRATION | FIELD CONDITIONS

D.1 Context and Approach

1. Everett Rogers in his seminal work Diffusion of Innovations[18] 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 measure 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.

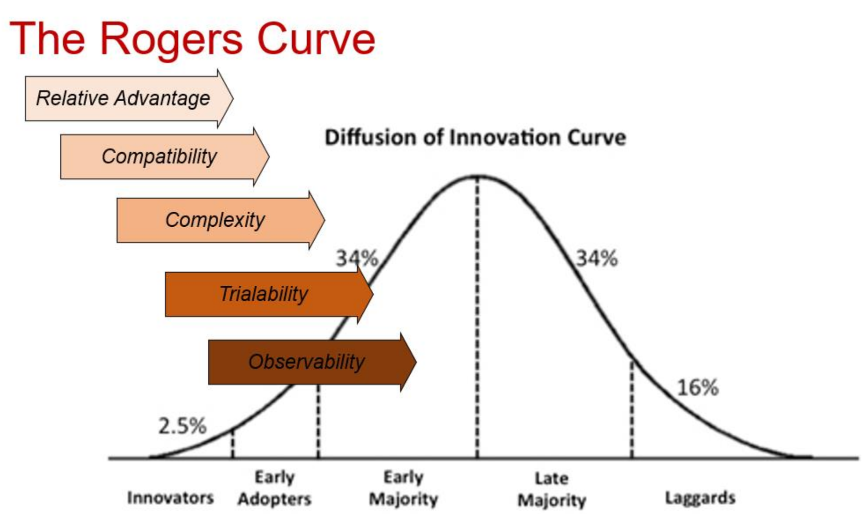

***Figure 11:** Characteristics of Innovations and the Diffusion Curve, Everett Rogers, 1962*

[18] Rogers, E. M. (1962). Diffusion of innovations. New York, Free Press of Glencoe.

2. **Partnership.** The AGNIi Mission has continued to strengthen its long-lasting partnership with the 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.

3. 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.

4. **Field Understanding.** The AGNIi Mission developed field understanding via repeated consultations across NDRF's stakeholders from field (from responders to commandant) to leadership (DG, IG, DIG). The Mission has gathered these field requirements across several exercises over an extended time period. This has included feedback from live support exercises involving AGNIi, such as during the Chamoli disaster response in Uttarakhand in 2021. 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. Below are the images from the Chamoli disaster rescue operation.

***Figure 12**: AGNIi Mission assisted with the deployment of Nano drones by Indian innovators for indoor surveillance in the Tapovan tunnel during the NDRF Chamoli operation*

5. **Technology Demonstration.** The AGNIi Mission continues to work with NDRF personnel across different tiers in understanding pain-points, operational scenarios and developing 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 13:** NDRF-AGNIi Virtual Technology Showcase (Jan 2022)*

6. **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.

Figure 14: *NDRF and AGNIi members in a powered rescue boat at Jadhavwadi Lake, Pune*

7. The Field Technology Showcase finds its base in the Diffusion of Innovation theory, more commonly known as the Rogers' Curve. As per the theory, the adoption of new ideas and products does not happen simultaneously in society but follows 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. The 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.

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

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

Figure 15: *Team AGNIi at the NDRF-SDRF Annual Conference, New Delhi (April 2022)*

D.2 Surveillance and Payload UAVs for Disaster Response

1. Surveillance as well as payload UAVs from different indigenous innovators were showcased and tested extensively in two field demonstrations with the 11th Battalion, Varanasi and the 5th Battalion, Pune of the NDRF, in Feb and May 2022, respectively. The showcases were conducted based on Trial Scenarios, jointly conceptualized by the NDRF and AGNIi Mission.

Figure 16: *Battery-powered Fully Autonomous Unmanned Helicopter with Day/Night Camera (40x Zoom)*

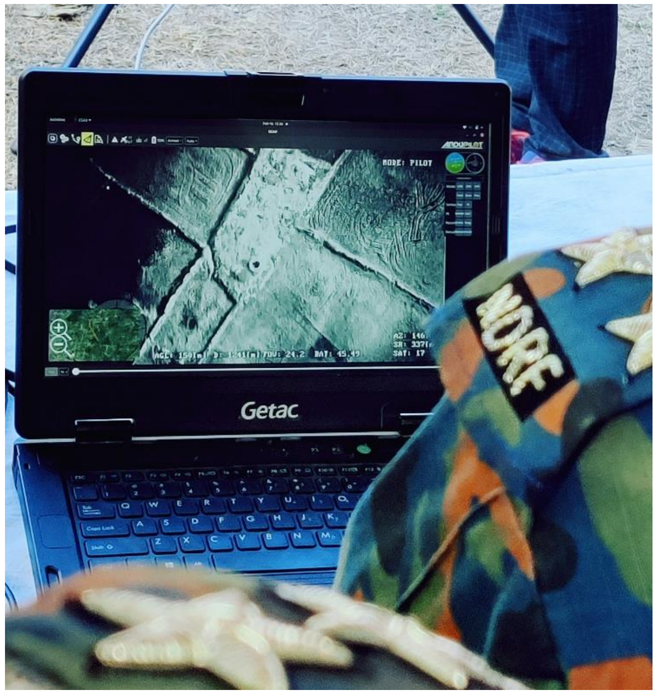

Figure 17: *NDRF Officers viewing the real-time feed during flight, sharing feedback with innovators*

Figure 18: *Hybrid VTOL design Logistics drone (~5kg payload)*

Figure 19: *Payload drone with 15L water tank was tested for dynamic firefighting capabilities*

Figure 20: *Fully autonomous payload drone (5kg capacity) with extended range (20km)*

Figure 21: *Manual flight of payload drone strapped with 4kg payload was carried out at test site, 5BN*

Figure 22: *Pre-programmed fully autonomous drone flight with 4kg custom payload was carried out from Jadhavwadi dam to 5BN HQ, Sudumbre (approx distance of 3km)*

Figure 23: *Gasoline-powered helicopter-design UAV was demonstrated for wide aerial video surveillance while the drone executes pre-fed flight routes in a fully autonomous manner.*

2. The Trial Scenario for Surveillance UAV given by NDRF:

> *"There was a major dam breach in Pune. Many people are believed to be stranded in isolated hilly patches seeking help. The victims may be located with the help of UAV. The co – ordinates of incident place are 18°48'28.33"N 73°43'41.16"E. Approximate aerial distance is 04 Kms. Bhamchandra Extension. The Co-ordinates of second incident place are 18°46'5.18"N 73°45'39.85"E. (Helipad at 05 BN NDRF, Aerial distance approximately 4.2 Kms)"*

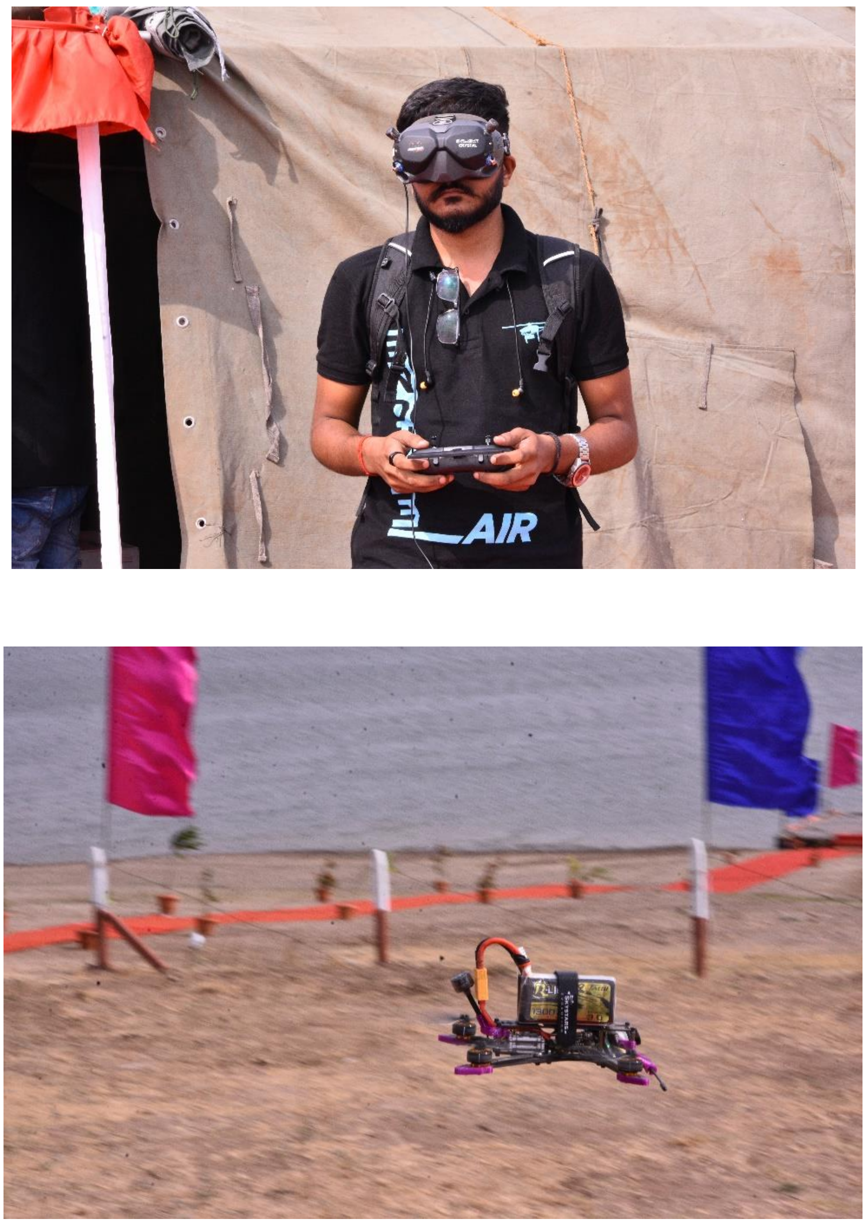

Figure 24: (A) *Drone Pilot with First Person View goggles;* ***(B)*** *Close-up view of the Nano-drone in flight*

3. Nano-drones for CSSR Rescue were demonstrated to the NDRF at their 5th Battalion, Pune in May 2022 with video feed being streamed to NDRF officers on a real-time basis.

Figure 25: (A) *DIG Training using the FPV goggles;* ***(B)*** *UAV passing through a collapsed structure.*

4. These trial scenarios developed by AGNIi were used for all the UAV demonstrations to NDRF:

Technology	**Trial Scenarios and Directives for Evaluation**
Drones for Situational Awareness and Response Payload Drop Capability Surveillance (Outdoors + Indoors) Specialized Purposes (Thermal, LiDAR, Stringing, Tethered)	Payload Drones – -UAV shall take-off from pre-decided coordinates and carry strapped sample package (food/water packet) to designated coordinates at 2-5km from start point -UAV to drop the package using winch or land and deliver package to stranded victim at desired coordinates Outdoor Surveillance – -For outdoor surveillance, UAV to relay real-time video feed to Command-and-Control centre along with live telemetry data for situational awareness and intelligence -UAV to be capable of manual control as and when desired, apart from regular flight in fully autonomous BVLOS manner -UAV should be able to navigate to coordinates of interest during flight, to simulate the exercise of locating survivors and crash sites. Indoor Surveillance – -Nano-drone to autonomously traverse entirety of the collapsed structure to find areas of alert, trapped victims (if any), hidden damages -Live video feed to be displayed on FPV goggles to the officers in board

D.3 Unmanned Surface and Unmanned Underwater Vehicle (Floodwater Rescue)

1. Indigenously developed Remotely operated Rescue Lifebuoy was showcased and tested extensively in two field demonstrations with the 11th Battalion, Varanasi and the 5th Battalion, Pune of the NDRF, in Feb and May 2022, respectively.

Figure 26:* *(A) *DIG Ops, NDRF interacting with the innovators regarding design and operability of the Lifebuoy;* ***(B)*** *Range and buoyancy of the lifebuoy being assessed at the Ganges in Varanasi, UP*

2. Based on the first demonstration to the NDRF at 11BN Varanasi in Feb 2022 and the subsequent feedback shared by the constituted board of officers, the innovator made the below changes to the lifebuoy before the 5BN demo at Pune in May 2022.

3. Design changes to the hull, self-righting structure and pillow, power improvements to the jet pumps, motor, radio communications and overall improvements to the maintenance box and charger were done by the innovator.

Figure 27: (A) *Victim rescue being demonstrated at the Jadhavwadi lake as officers observe and assess performance;* ***(B)*** *Close-up view of the upgraded lifebuoy with the NDRF diver who participated in the exercise*

4. Autonomous Unmanned Marine Surface Vehicles (UMSV), roughly the size of search and rescue boats used by the NDRF, were demonstrated at the Jadhavwadi Dam, 5th Battalion NDRF, Pune.

Figure 28: ***(A)*** *Side view of the UMSV;* ***(B)*** *Front view of the UMSV, Catamaran Hull design*

Figure 29: (A) *The UMSV cruising at 4-5 knots in Jadhavwadi Lake;*
(B) *Payload carrying capacity being demonstrated; 6 adults were onboard with slow movement.*

5. These UMSVs are designed as per military standards and incorporate removable floats and dynamic positioning. They are capable of autonomous traversal and navigation in large water bodies and can be integrated with cameras and sensors for real-time data gathering and intelligence. In floodwater rescue and cyclonic conditions, these unmanned boats can be deployed for identifying trapped victims, rescuing them, and aiding the manned boats in operations and logistics.

6. High-performance, modular, ROV for Underwater operations was demonstrated to the NDRF at the Jadhavwadi dam under the jurisdiction of the 5th Battalion in Pune.

7. The ROV is tethered (300m tether length) to an external power source and control station via a 2-way data transmission and power cable and is equipped with cameras, sensors, SONAR etc. for self-navigation and guidance and to scan objects underwater. The ROV has a vector thruster configuration giving a max 2 knots speed and thus is capable of omni-directional movement, with a deployment depth of 100m.

***Figure 30:** Tethered ROV being deployed underwater for a dummy human body detection exercise*

Figure 31: *NDRF officers interacting with the innovator and viewing live feed and SONAR data at the ground station*

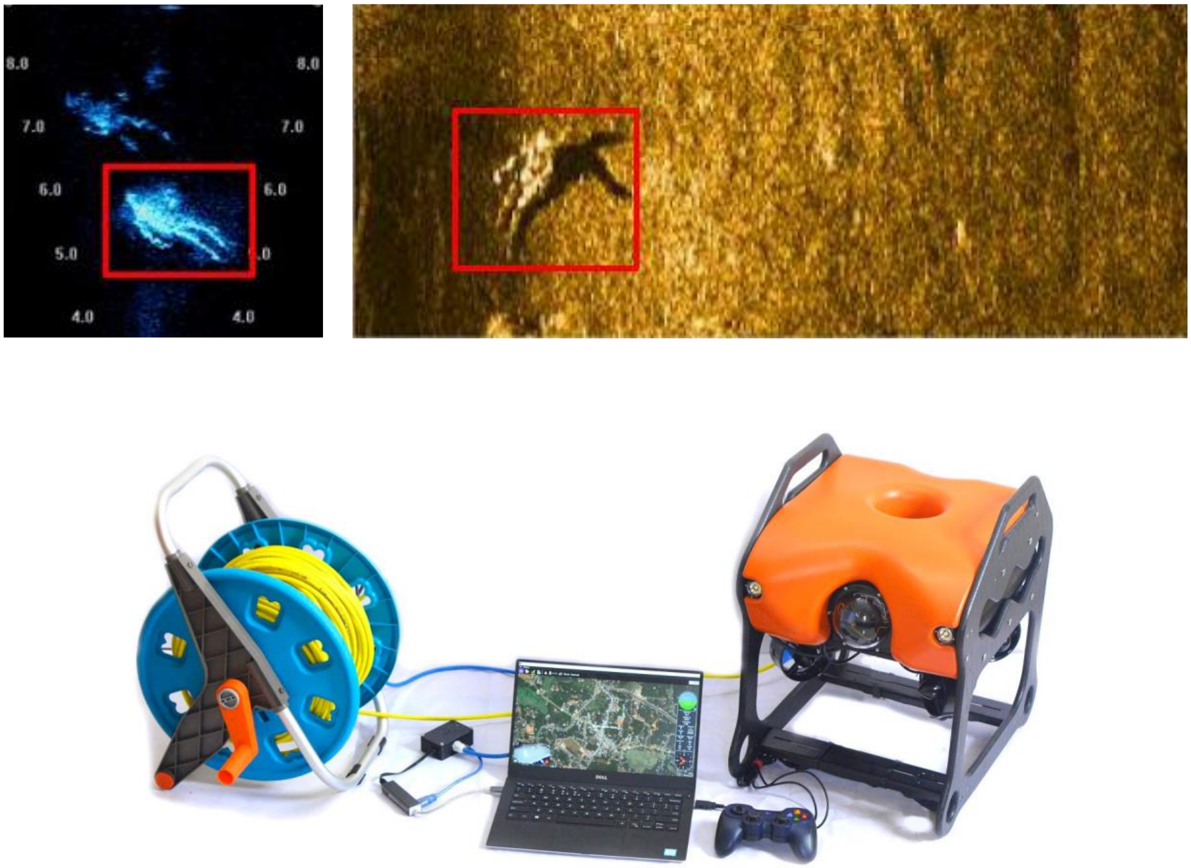

Figure 32: *Sample images of Imaging SONAR, dehazed video feed from the ROV, ROV + Control Station + Tether*

8. The below trial scenarios developed by AGNIi were used for all the USV and UUV demonstrations to NDRF:

Technology	Trial Scenarios and Directives for Evaluation
Underwater Remotely Operated Vehicle (ROV)	Visual Inspection - ROV will be deployed from the safe landing area of the dam and piloted. Customization fittings may be attached to ROV during this operation to protect the equipment from any obstruction objects. Visual footage of the dummy human body/ Diver shall be recorded and viewed live on screen. Imaging Sonar - Sonar shall be installed on ROV. Sonar will be utilized to detect the dummy/diver on the dam floor. Once Dummy/Diver is detected ROV shall be commanded to approach close to dummy/diver to record the clear visuals using HD camera.

Technology	Trial Scenarios and Directives for Evaluation
	Gripper arm - Gripper arm shall be used to attach hooks and lines or to grab onto objects for station keeping. Navigational Capability Demonstration - ROV will be piloted over a range of 100mtr on DAM (sic). All the piloting modes like 'Heading Holding, Depth Maintaining' will be performed here. Control console and software usage will also be demonstrated.
Unmanned Marine Surface Vehicle (UMSV)	- Carrying adequate load: Equipment, personnel across the lake - Parallel working with NDRF manned boats to test seamless operations - Detecting personnel across the lake to test long range vision - UAV deployment in conjunction with UMSV - Search and rescue capability for night operations
Rescue Lifebuoy	- Reach target within seconds to ensure survivability of the victim. - Adequately deal with frantic movements of the victim without capsizing. - Victim should not need to push: Pull victim through water, despite current across the dam. Lack of currents can be compensated for through longer distance as motor capacity can be tested. - Lifebuoy must not spin when held by the victim, must be minimal for easier navigation.

9. The Trial Scenarios given by NDRF for Floodwater Rescue technologies were:

   a. Underwater ROV

      "A motorcycle accident had happened near Jadhavwadi Dam. Two persons along with motorcycle have been drowned in the water. DM Pune has sought the help of NDRF teams. You are therefore directed to locate the victims and to extricate them with the help of Underwater ROV.
      The co – ordinates of incident place are 18°46'30.35"N 73°43'34.17"E
      Possible co-ordinate of victim can be 18°46'30.66"N 73°43'33.31"E."

   b. Rescue Lifebuoy

      "There is a boat capsize at Jadhavwadi Dam. Many people are trying to save their lives by improvised floating devices. DM Pune has requisitioned the help of NDRF. The victims may be rescued with the help of Life Buoy. The co – ordinate of incident place is 18°46'55.17"N 73°43'12.00"E (Approximate aerial distance is 800 Meters – 900 Meters.)"

   c. Unmanned Marine Surface Vehicle

      "There is a vessel capsize due to the collision between two vessels. Many people are believed to be drowned and many are trying to save their lives by improvised floating devices and

the level of water current is very high due to adverse weather conditions. The victims may be rescued with the help of UMSV to evacuate the victims to the safety. The co –ordinates of incident places are: A.18°46'43.50"N 73°43'31.51"E, B.18°46'29.81"N, 73°43'28.44"E."

D.4 Performance Matrix

1. This section summarizes the idealized technological capabilities of the innovations vis-à-vis the performance and parameters of these innovations as assessed during the field technology showcase. The key objective of the performance matrix is to help the adopter in understanding the extent to which the technological capabilities tackle the adopter's pain points, thereby aiding in the deployment of force personnel training exercises.

Feature	Unmanned Aerial Vehicle	Unmanned Ground Vehicle	Unmanned Surface Vehicle	Unmanned Underwater Vehicle	Performance Assessment
Long range reconnaissance	UAVs have a significant range, sufficient to cover any area of operation. Battery and range of connectivity limitations are few.	-Ground vehicles are currently limited in their range due to terrain and design considerations. If optimized for distance, their ability to carry heavy payload is compromised. -Further, if range is of preference, then a UAV may serve the function better.	-Surface vehicles serve a unique need. They can used for long range operations in flooded areas for search and rescue of distraught citizens.	-Wirelessly operated UUVs can be used for long range operations. Such operations are largely outside the domain of NDRF. -NDRF can use these technologies for underwater search and rescue, benthic mapping.	-The four avatars of the unmanned technology provide a range of options for optimizing on multiple parameters of range, payload and type of operations.
Real time intelligence feed	Due to their bird's eye view capability, they can provide real time intelligence, information depending on payload attached (day camera, thermal camera).	-Due to the nature of vehicle, real time intelligence function is served better by USV and UAV; -Movement through high temperature regions due to rugged build;	-USV provides similar capabilities as a UAV in terms of speed. -However, they are limited by the water body, its nature (cluttered-debris prone, clear) and flow	-UUV enables a underwater feed that fills the gap left by others. The ability of low-cost deployment, not limited by the skills and endurance of the diver, provide previously	-Real time intelligence can be obtained in multiple formats (camera, LiDAR, heat mapping), various perspectives (birds eye view, underwater, up-close and

			of water (urban flood, choppy waters).	unobtainable inputs.	magnified) and different benefits. -These multiple options enable a cafeteria approach to technology selection.
Agile movement	Form factor and design decide the agility. Due to least friction (compared to other unmanned vehicles).	-Ground friction is higher for both track and wheels. UGV are limited by this constraint. Further, the ground may be cluttered and obstacle rich, rendering quick movement and change of track impossible. In a jungle terrain, track and wheels will be impeded by the forest ground. Similar limitations will be faced in other terrains.	-USV can be designed to be agile. Agility acquired through shape and weight will need to be optimized with capacity to navigate choppy water through its crests and troughs.	-Significant drag experienced by the UUV will limit the movement and its speed.	-All four technologies have the potential to be agile in their movements. UAVs of small form factor can be used in collapsed structure search and rescue, UUV can be agile in its movements underwater. -However, friction and drag (for UGV and UUV) will limit this. These hard constraints will need to be factored in at the time of operation.
Load delivery	If the primary consideration for load delivery is height/difficulty of reach where time is of the essence, UAV can deliver immediate relief material.	-Significantly more weight (few hundred kilograms) can be carried by SAR team to limited extent.		-Load delivery though possible, will require a UUV size that would fall outside the operational mandate of disaster rescue forces.	-Payload delivery can be achieved well through all four Unmanned vehicles. -Depending on the critical factor (weight, time, terrain) the end user can select the technology most suitable.

D.5 Collaborative Unmanned Vehicles

1. The concept of having multiple Unmanned Systems work together by making use of each one's versatility and advantages to achieve enhanced capabilities and performance in hostile environments can be termed Collaboration or Cooperation in Unmanned Systems.

2. UAVs meant for maritime operations are capable of vertical take-off and landing (VTOL) from dynamic moving positions/coordinates. Advanced control system algorithms take care of the adjustments in rotor speeds, flight parameters and dynamic stability and positioning of the UAV. Real-time precise adjustments are made based on the movement of the landing station which is typically a marine vessel with a flat area for VTOL. A temporary landing pad was mounted on an NDRF rescue boat and the take-off of the UAV, aerial surveillance and landing back on the same pad while the boat was in motion, was demonstrated successfully. The same landing pad when mounted on the Unmanned Marine Surface Vehicle, described in the previous section, followed by a similar exercise by the UAV, reinforces the importance of collaboration between Unmanned systems to unlock capabilities that do not exist when these systems operate in silos or in an independent manner.

3. An example of the above was demonstrated to the NDRF at the Jadhavwadi Dam during the showcase with the 5th Battalion, Pune in May 2022.

***Figure 33:** Autonomous UAV preparing for an approach to the rescue boat with landing pad*

Figure 34: *UAV performing a dynamic landing on a moving rescue boat, in a fully autonomous mode*

Figure 35: (A) *UAV at the landing station with the team of engineers;* ***(B)*** *Close-up view of UAV during flight*

D.6 Technology Assessment and Evaluation

1. A board was constituted on 20th April 2022 by NDRF for the evaluation during the field showcases in May 2022.

2. The technology-based parameters given below were used to assess the technical capabilities of each of the technologies, compare them with similar technologies as well as match them to force's functional requirements.

3. Technology-based Selection Parameters:

    a. All UAV related technologies and its capabilities were evaluated based on the below parameters:

Technology	**Assessment Parameter**
Drones for Situational Awareness 1) Payload Drop capability 2) Surveillance	1. Sensing and Imaging Payloads (RGB, IR, LiDAR, Multispectral etc.) 2. Endurance (in mins) 3. Custom Payload carrying capacity (in kg) 4. Altitude & Ceiling (in feet) 5. Operational Range (in km) 6. Power System (Electric/Gasoline) 7. Autonomy features (RTH, Parachute, Obstacle Avoidance and detect and avoid) 8. Wind/Gust Resistance (kmph) 9. Deployment time (Ready to fly in) 10. Weather resistance

Figure 35: *Twin Rotor VTOL UAV with Payload and Surveillance capabilities (Representative Image)*

b. All Floodwater Rescue technologies and its capabilities were evaluated based on the below parameters:

Technology	Assessment Parameter
Underwater Remotely Operated Vehicle (ROV)	1. Operational Depth 2. Thrust, Tether, Omnidirectional movement, Degrees of Freedom 3. Telemetry Data Overlay in Real-time 4. Payload (SONAR, Echo Sounder, Cameras etc.) 5. Dehazing, enhancement of Audio/Video feeds 6. Predictive Intelligence Layer 7. Maintenance and Repairability
Unmanned Marine Surface Vehicle (UMSV)	1. Cruise Speed 2. Payload Capacity 3. Endurance 4. Disaster Response Capabilities (e.g., detachable floats) 5. Systems and Sensors (SONAR, Cameras, SATCOM etc.) 6. Autonomous Capabilities (Navigation, SAR etc.) 7. Design Material, ruggedness standards
Rescue Lifebuoy	1. Battery capacity/Endurance at cruise speed 2. Telemetry Range 3. Weight capacity 4. Construction Material 5. Wind resistance 6. Water current resistance 7. Autonomous capabilities 8. Stability/Buoyancy

Figure 36: *Unmanned Autonomous Marine Surface Vehicle (Representative Image)*

D.7 Adoption Levers

1. Everett Rogers in his seminal work Diffusion of Innovations[19] 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 measure 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.

2. The perceived attributes of innovation are instrumentally important. This is because end adopters are force personnel at the operational tier and it is imperative that clarity is maintained with respect to both functionalities and the benefits of technology innovation pertinent to their use. In this context, one of the key objectives of the Field Technology Showcases is to exhibit and contextualize the above attributes of innovation both to the decision makers and the end adopters.

3. The subsequent tables 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.

[19] Rogers, E. M. (1962). Diffusion of innovations. New York, Free Press of Glencoe.

#	Adoption Levers	Technology / Operational Scenario Summary	How did the Showcase achieve this?
1	**Relative Advantage**	Unmanned systems can provide several relative advantages for disaster response forces, like – **Time savings:** Unmanned systems can operate around the clock without rest or downtime, allowing for quicker response times. They can survey disaster areas more quickly and efficiently than human teams, providing critical information to the disaster response force's command center. This rapid response can enable faster decision-making and reduce the time required to provide aid to affected populations. **Risk reduction:** Unmanned systems can reduce the risk of injury or death to disaster response force personnel by performing dangerous tasks, such as search and rescue operations, in hazardous or unstable areas. This risk reduction can help keep personnel safe and improve their overall well-being. **Enhanced capabilities:** Unmanned systems can perform tasks that are difficult or impossible for humans to accomplish, such as accessing areas that are inaccessible or dangerous to human teams. They can also carry heavy payloads, deliver critical supplies, and provide real-time information that can help the disaster response force make informed decisions.	Factors like time saving, risk reduction and enhanced capabilities were demonstrated via Unmanned Aerial and Water systems demonstrated at 5BN, NDRF, Pune.

		Cost savings: Unmanned systems can provide cost savings by reducing the need for human labor and equipment. They can also help disaster response forces save money on fuel and transportation costs. These advantages can help disaster response forces respond to disasters more effectively and efficiently, improving their ability to save lives and provide aid to affected populations.	
2	**Complexity**	Unmanned systems for disaster response should be relatively simple to operate and maintain. They should have a user-friendly interface, and the necessary training should be provided to the operators to handle them effectively. The unmanned systems should be easy to repair in the field if any damage occurs. Additionally, they should be designed to integrate seamlessly with other technologies that are already in use by the disaster response force.	The interface, operating procedure and handling were demonstrated at the showcase. Maintenance, Training and Integration with other technologies will come in once the force adopts these systems at a larger level.
3	**Compatibility**	Unmanned systems should be compatible with the current technology and equipment used by disaster response forces. They should be able to interface with existing communication and control systems to allow for seamless integration into the disaster response force's operations. Compatibility with other unmanned systems should also be considered to enable collaboration and coordination between different unmanned systems.	The FTS sought to demonstrate compatibility or obstacles to it by giving the Force the chance to pilot the UAV for multiple use cases that are critical to them: Rescue in Ganga (Flood water rescue: USV); payload delivery in Pune and Varanasi (relief material in UAV). These exercises brought out factors of

			compatibility and factors of obstacles such as training requirements, such as the low capacity of USV to drag a person drowning safely to the shore.
4	**Trialability**	Unmanned systems should be easy to trial and test in various disaster scenarios. They should be versatile enough to perform different tasks and adapt to various conditions. Disaster response forces should have access to the unmanned systems to test their capabilities and determine how they can integrate them into their operations.	The various unmanned systems were tried and tested to different trial scenarios at the showcase checking multiple capabilities during the showcase.
5	**Observability**	Unmanned systems should be observable to allow disaster response forces to monitor and track their progress effectively. The unmanned systems should provide real-time data, including video footage, sensor data, and other critical information, to the disaster response force's command center. This observability will allow disaster response forces to make quick and informed decisions.	The unmanned systems provided real-time data, video footage, sensor data and other telemetry information to the command-and-control center setup during the showcase.

PART E | WAY FORWARD | ASSESSMENT AND ADVISORY REMARKS

E.1 Summary

1. Hostile environments, such as disasters/calamities, infrastructure collapse, pose serious concerns to humanity and vital assets. To improve rescue capabilities of the force personnel and increase their own survivability against the hostile elements of nature, one must possess a robust strategy and plan, combination of people and technology followed by an efficient execution and delivery process.

2. Unmanned Systems form an essential part of the technology arsenal that differentiates a force during such arduous situations. They can conduct repeated recce and intelligence gathering exercises, alert troops to any potential threat or perpetration and operate in synchrony with the troopers during operations. These systems are significant force multipliers across all three mediums of operation: land, air, and water.

3. The AGNIi Mission conducted multiple interactions with NDRF personnel to understand ground-realities, existing technology equipment being used and operational scenarios of the force for each problem that they face. These were then translated to use-cases for which technology stacks depicting the layers of the solution, workflow and available technologies at each layer were created and reviewed with force personnel. Based on these stacks, Indian innovators with relevant capability were identified who then demonstrated their technologies at field showcases jointly conducted by AGNIi and the force.

4. Based on the assessment and evaluation of these technologies at the field showcases, the force must shortlist technologies that partially/fully match requirements, suggest customizations for iterative product improvisation and recommend technologies to the technology/provisioning directorate at force headquarters for either a small-scale trial procurement for further testing the suitability of technology in real-world scenarios or update the Qualitative Requirements and Trial Directives associated with tenders for force wide large-scale procurements.

5. In the field of Unmanned systems, a wide array of technologies was identified and demonstrated to the NDRF. The team at AGNIi Mission continues to work with different law enforcement agencies, internal and border security forces as well the disaster response force to understand their evolving operational mandate, identify use-cases for emerging technologies and demonstrate the use, potential and applicability of indigenous technology in near real-world scenarios created at exemplar project locations.

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.

Strategic Context	Operational Context	Idealized Capability	Capabilities indicated in Showcase	Recommended Course of Action
Extended, continuous personnel functioning in time-contingent situations. Destroyed infrastructure environments. Victim rescue from collapsed structures, flooded areas imposing	**Payload Delivery**	-An unmanned system should be able to deliver a payload, without compromising on its agility and endurance. Further, it should be able to carry multiple types of payloads. The marginal increase in fuel consumption due to increasing weight should be minimal.	-Payload drones have been trialed at Pune and Varanasi for NDRF. The payload drop through winch and landing was found to be satisfactory. The weight of payload capacity (5kg) at Varanasi was sufficient.	-NDRF should consider empaneling firms so it can call on them to deliver as per the agreement. This will enable a country wide reach of drones, as well as minimize purchase and MRO operations for the force. The Force should consider all four Unmanned systems as all are applicable to its use cases. A Service Level Agreement be signed to enable this engagement.
	Wide Area surveillance	-Intelligence inputs out of wide area surveillance should be real time, granular and actionable and intelligence should be	-Ruggedized Surveillance drones with high resolution optical payloads were	-The above two recommendations notwithstanding, the force may consider identifying the payloads most relevant for it. This will be day camera, LiDAR, SONAR for visual intelligence, 3D Mapping that can enable vulnerability maps, real time operational

constraints on mobility and accessibility. Real-time intelligence and inputs to enable a common operating picture.		interpreted and contextualized to enable speedy action.	Showcased in Varanasi.	feedback. The Force may consider working with a firm that provides actionable intelligence out of drone feeds. These may be separate innovators.
	Confined space surveillance	-Small form factor of nano drones should enable it to navigate confined spaces. Autonomous operations should prevent collisions despite agile movements, endurance should be high enough to search multiple victims/debris/houses	-Nano Drone: It was able to establish its agility and maneuverability as it could move through small windows, provide video feed. Endurance was found to be satisfactory for the quick search and locate operations.	-Confined spaces in collapsed search structure rescue, is an integral part of force operations. A standalone nano drone be acquired per battalion to ensure that time critical operations are not impeded by SLA limitations (mentioned above).
	Floodwater Rescue	-The USV should be fast enough to reach victims in time, agile enough to avoid debris, motor should be sufficiently powerful to overcome current and pull the victim to safety despite a distraught, flailing victim.	-The USV was found to have satisfactory speed and agility. However, the weight of the vehicle and its motor were unable to overcome the river currents and pull the victim.	-Floodwater rescue makes the most pressing demand on the force due to its frequency and scale. -The Force may consider acquisition of a USV for floodwater rescue. This will need to be considered against the realities of these operations: Speed and debris prone current, ability of USV motor to hold steady under such duress etc. -The Force may consider a **cooperative research and development agreement** with the innovators. This is because the disaster response forces are a niche market for this technology. -**Advanced Market Commitments** may be considered to create incentives for the innovator.

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