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Militarisation of 5G: A Necessity for the Forces

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Key Points

- National Policy or a 5G Strategy is the need of the hour for spectrum management & utilisation.
- Research organisation, fusion of the 'iron-triangle', is need of the hour for internal and collaborative R&D.
- In-house development of hardware and software followed by validation of technology by using of test- beds, should be worked upon.
- India should focus on terrestrial & non-terrestrial links, which would be unique to the forces' requirements.
- Supply chain needs to be regulated in order to cater to full rollout of 5G technology and facilitate its expansion thereafter.

Abstract

5G holds the promise of ubiquitous high speed data connectivity; vastly improved intelligence, surveillance & reconnaissance (ISR); fast and secure command & control; more efficient logistics; swarming unmanned vehicles, and wide use of virtual reality (VR) and augmented reality (AR). The forces have very well understood the importance of this 'next generation communication network'. The Armed Forces needs to leverage this technology for optimal use; concurrently develop one's own terrestrial & non-terrestrial networks and finally integrate it as a robust & secure joint forces network, fully interoperable at all levels. Keeping this in mind, there is a felt need to issue a National Strategy for Implementation. Therefore, a research body which looks at spectrum management issues needs to be established; it should also be implemented in the theatre commands within a definitive timeframe. Test-beds need to be activated to validate the inherent technologies and gauge the results achieved. An organisation which caters to these requirements is the need of the

hour so that the project reaches completion and modifies the networks as a hybrid public-private network model or purely a model meant for the forces which is completely secure with the user and control plane under military control. Collaboration and internal R&D will help the armed forces reap benefits of this communication technology as well as pave the way for networks which are 'Beyond 5G' (B5G).

Introduction

Wireless innovation plays a key role in integrating various emerging technologies into tangible results across the nation. 5G technology—the next generation transformative technology in the communication domain— has taken the world by storm. Military too, has included this technology in its day-to-day functions— 5G seems to be increasingly used by militaries of countries across Europe, China and the USA.

5G technology will also play a key role in the future battle network; with the capability of simultaneously linking millions of transceivers within a defined area, it will enable military personnel to transmit to one another—almost in real-time— maps, photos and other information about the operation under way. Due to its lightning fast transmission speed and the capacity to cope up with the approaching tidal wave of data communication, this emerging technology will lead the way to innumerable critical IoT applications where data is captured and acted upon virtually. Immersive technologies like virtual reality and augmented reality once installed with 5G, are going to radically change the way we interact with our environment.

As the world is moving towards 6G, the Indian Armed Forces should formulate a 'National Strategy for 5G Implementation' and incorporate 5G as a major dual-use technology that will return timely dividends. It is this aim that is being addressed as part of this brief.

Technology Brief: 5G Jargon

Figure 1: Components of 5G Technology

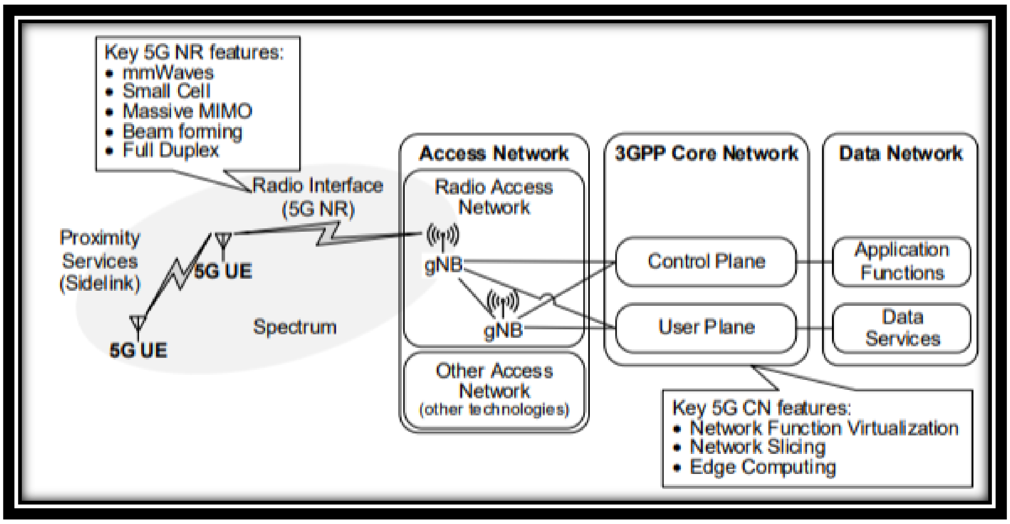
Source: https://www.itic.org/policy/ITI_5G_Full_Report.pdf

International Mobile Telecommunications (IMT) 2020 identifies the following as distinctive features of 5G technology[1] (**Figure 1 above**):

- ***Enhanced mobile broadband (eMBB).*** These are traditional services that are being provided by 5G technology. It involves high traffic bandwidth, high speed data for large density of users with low to medium mobility. This will aid in last mile connectivity for users. The 3rd Generation Partnership Project (3GPP) has planned the implementation of this basic feature in two phases—*Phase I* looking at interoperability with the 4G/ LTE services and ***Phase II*** (2016 onwards) towards implementation of the three key features listed herein.
- ***Ultra-reliable and low latency communication (URLLC).*** Low latency (latency is the the delay involved in transfer of data) and high availability of data services for applications not requiring high throughput but requiring high connectivity in mobile scenarios.
- ***Massive machine type communication (mMTC).*** These communications cater to IoT connectivity for a near real-time data connectivity.

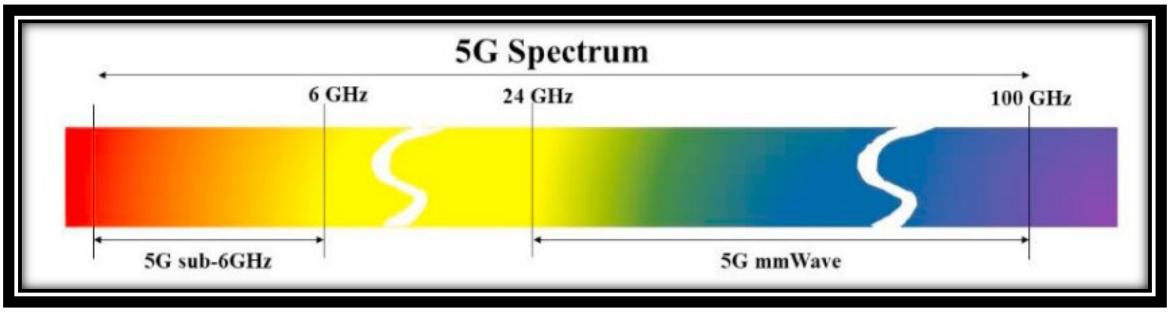
A simplistic way to understand the 5G network is shown in **Figure 2 below**. UE which is the user equipment, under 5G can be transformed into personal equipment, vehicles and other such devices where inter-device communication is feasible. The access network is a new concept that comprises several technologies such as 4G, LTE, WiMAX, WiFi. The 5G 'New Radio' (NR) consists of next generation NodeB (gNB) or the base stations as they are commonly called.[a] The core network separates the control plane from the user plane—the former controls the network and the latter provides the user with various facilities such as QoS.

Figure 2: 5G Network- Simplistic View



Source: Bastos, L., Capela, G., & Koprulu, A. (n.d.). Potential of 5G technologies for military application

Figure 3: 5G Spectrum



Source: *Bhardwaj, Anshu, "5G for Military Communications" Procedia Computer Science, vol. 171, 2020, pp. 2665–2674, 10.1016/j.procs.2020.04.289*

[a] Generation NodeB gNB is the logical 5G radio node, the equivalent of what was called NodeB in 3G-UMTS and eNodeB or eNB (i.e. evolved Node B) in 4G-LTE.

The data network (internet or similar) are important for running application functions and services. Certain other terminologies which are necessary to understand in the case of 5G are the issues of spectrum, network virtualisation, network slicing and edge computing.

Spectrum

The spectrum of 5G is shown in **Figure 3** above. The frequency bands can be divided between **Low** (sub 1 GHz), **Medium** (1 to 6 GHz) and **High** (above 6 GHz or mm wave). As for India, the National Frequency Allocation Plan 2018 have also listed the 'frequencies of interest' to tap this technology—"the IMT 2020 or 5G services with its enhanced capabilities is relevant to cut across industry verticals. To take advantage of 5G services for Digital India, the millimetre bands vis. 24.25, 27.5, 31.8, 37 GHz and bands below 6 GHz are under active consideration and are subjected to co-existence studies and global deliberations".[2] Recent reports also suggests the allocation of mid-band spectrum in 5G services,[3] which is about 3.3 to 3.6 GHz bands.

3GPP Release 15, defined 5G frequency bands in a different way—as **Frequency Range 1** (FR1 – 410 to 7,125 MHz) and **Frequency Range 2** (FR2 – 24.25 to 52.60 GHz). Since, 5G near radio (NR) utilises both FR1 and FR2, therefore, it provides large carrier bandwidths. The physical layer consists of technologies such as time division duplex (TDD – multiple time slots for users) & frequency division duplex (FDD – different narrowly placed frequency bands) with millimetre wave (mm wave) using TDD extensively. Use of MIMO [b] Technologies, with active beamforming antennae, are also part of this layer. Proximity services (ProSe) also forms a part of 5G technology, mainly addressing the issue of distress calls as it is based on device-to-device communication and does not rely on the radio access network (RAN).

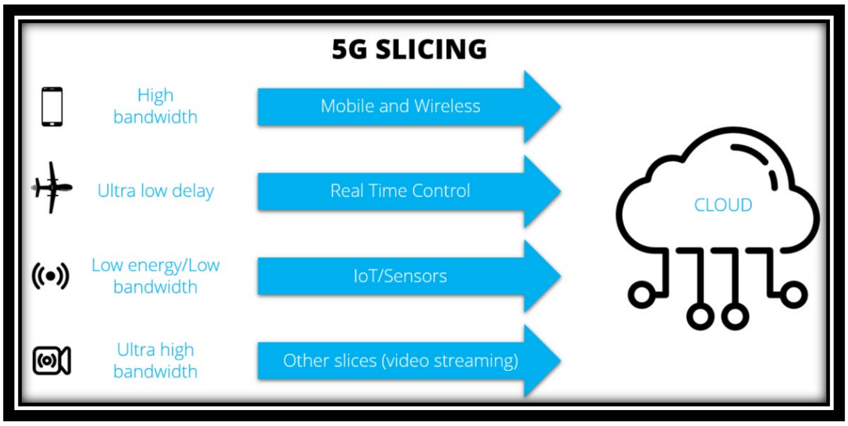
Network visualisation, Nework Slicing and Edge Computing

The core network carries out three main functions — network virtualisation, edge computing and network slicing; slicing refers to the breaking up of the entire network into subsets/ slices with each slice serving a particular function or needs of a customer (**Figures4 and 5**). 5G enables the resources to be provided as a service right at the RAN (edge computing).

[b] Multiple-In, Multiple-Out (MIMO) communication sends the same data as several signals simultaneously through multiple antennas, while still utilising a single radio channel. This is a form of antenna diversity, which uses multiple antennas to improve signal quality and strength of an RF link.

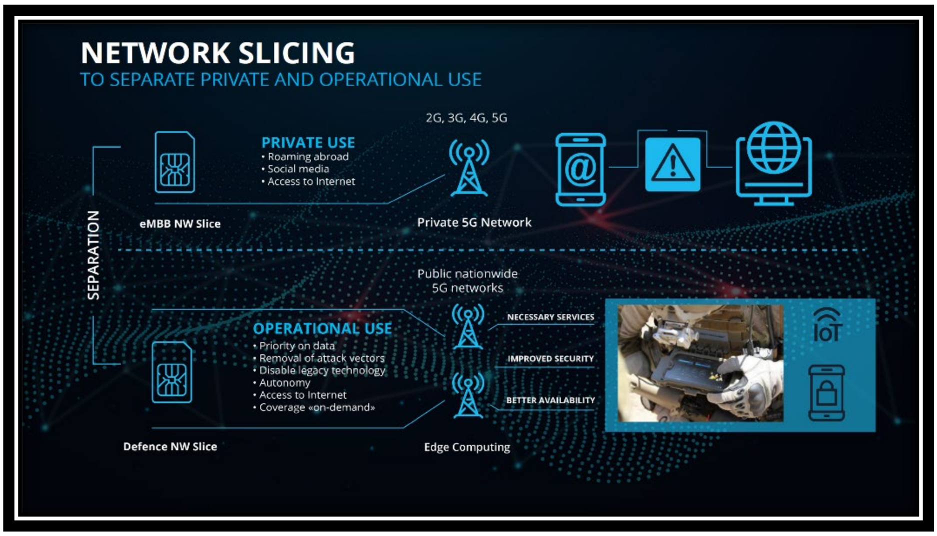
This consequently reduces the network latency & meets the requirement of faster computation and better throughput.

Figure 4: Schematic to Explain Network Slicing



Source: *5G is a game changer for the military* | *Data Responds*

Figure 5: Schematic to Explain Network Slicing – Military Use



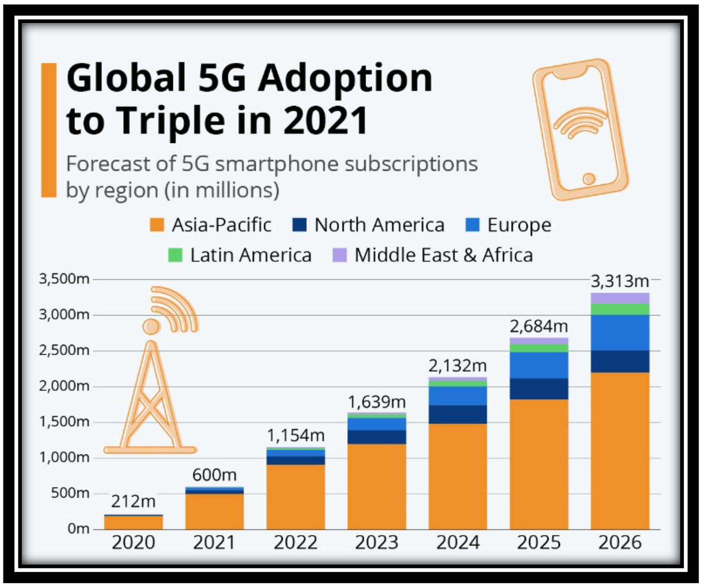
Source: https://datarespons.com/5g-is-a-game-changer-for-the-military

A critical aspect of 5G comprises of 'Non- Terrestrial Networks' (NTN) which enables last mile connectivity without much dependence on the terrestrial backbone. Methods such as high altitude pseudo-satellites and LEO satellites may be used in such a case.

5G Coverage: World Landscape

The game changing aspect of 5G technology, owing to Software Defined Network & Virtualisation techniques, have resulted in test-beds carrying out validation exclusively for the defence forces (5G defence slices). Nearly 3500 million subscribers of this technology are expected by 2026 [4] with the spread as shown in **Figure 6 below**.

Figure 6: 5G Worldscape



Source: Ericsson Mobility Report, November 2020

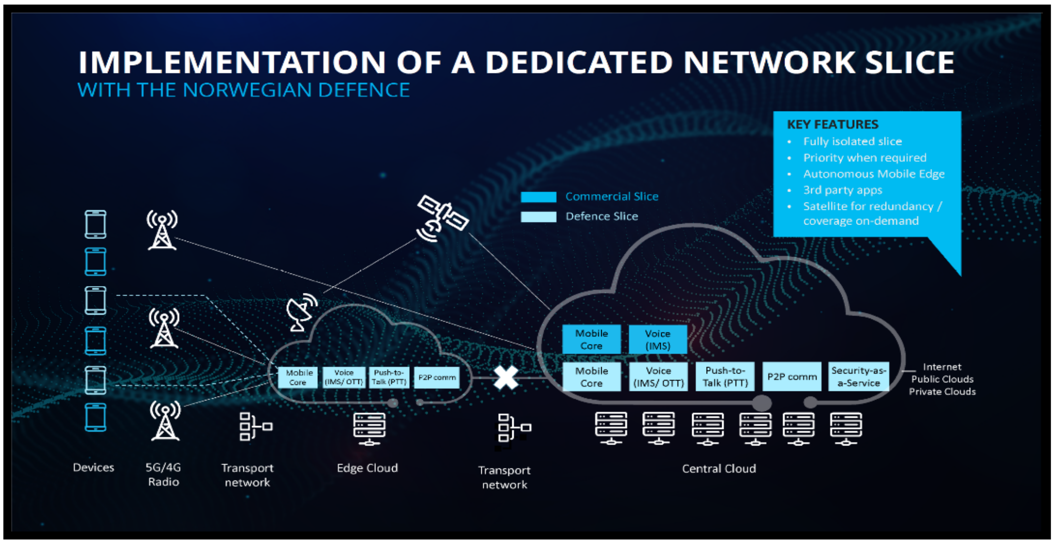
For countries such as USA, 5G is seen as a backbone for establishing the Joint All-Domain Command and Control. [c]

or JADC2[5] apart from the exploitation for civil use. According to an assessment, China is the current leader in sub-6 GHz technologies and is likely to deploy the world's first 5G wide-area network.[6] There have also been reports of the 5G network being installed in Tibet[7] (Ganbala radar station). The conceptualisation of 5G network, as seen in the Norwegian Defence forces, is shown in **Figure 7 below**. Use-case analysis of 5G has also been covered in a report of the World Economic Forum[8]. Based on the various features of 5G as

[c] Joint All-Domain Command and Control (JADC2) is Department of Defense's (DOD's) concept to connect sensors from all the US military services—Air Force, Army, Marine Corps, Navy, and Space Force—into a single network.

envisaged, by 2025, 5G technology would be used in all areas starting from smart homes and factories to extensive IoT based applications including autonomous cars, AR & VR.

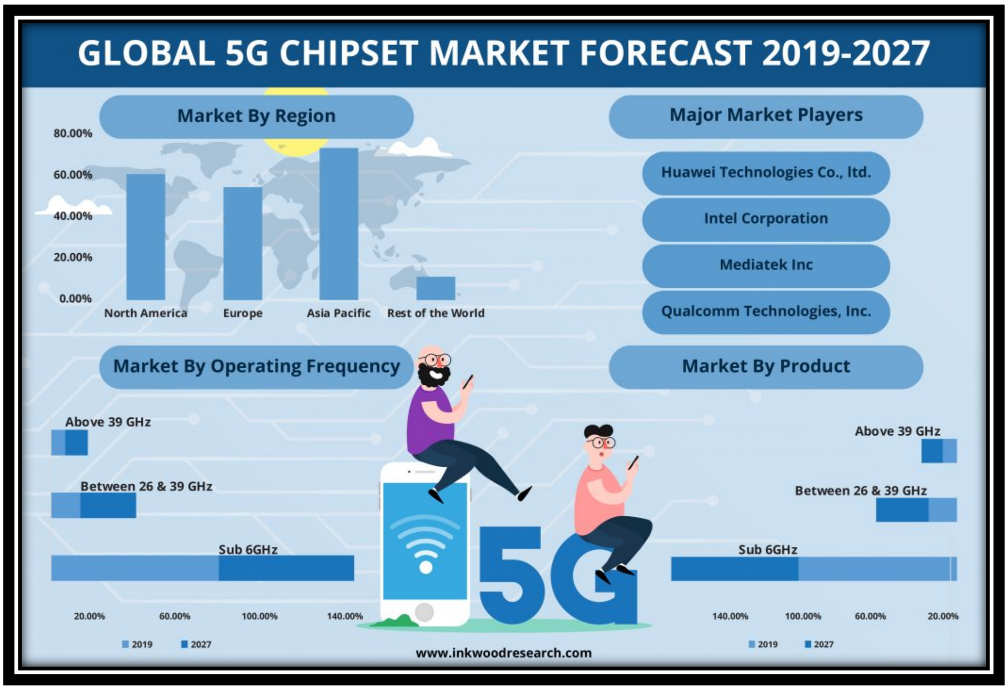
Figure 7: Network of 5G – Norwegian Defence



Source: https://datarespons.com/5g-is-a-game-changer-for-the-military

Slightly delayed, Israel too has joined the bandwagon of 5G rollout and has granted spectrum access to three service providers.[9] UK and Germany are also exploring co-operation means in this regard and inviting NATO to be a major role player.[10] Initially, Vodafone had launched these services in Germany in 2018.[11] The Russian deployment of this technology saw initial roadblocks due to indecision regarding the spectrum allocation—3.5 GHz band was not available in Russia due to satellite use. The next alternate was 4.8 GHz band. Majority of the countries implementing 5G[12] have accepted the 3.5 GHz band due to large coverage afforded by it. The global market forecast on 5G technology with special emphasis on the chipsets is shown in **Figure 8** below.

Figure 8: The Global 5G Ecosystem & Market Forecast



Source: *https://www.inkwoodresearch.com/reports/5g-chipset-market/*

5G Military Technology Ecosystem Development

Having seen the civilian use-cases as well as the projected figures for its growth, the immense potential that this technology can offer to the military can only be understated—"5G is not only a leap in communication technology, but also an integration of artificial intelligence, cloud computing, internet of things and other emerging technologies to promote intelligence operations, high-speed sharing of massive battlefield resources, and accelerate the release of its war potential".[13] In a standalone pure communication aspect or with its fusion with other contemporary technologies, there are a plethora of places where 5G holds promising results. However, there are differences when we want to list out the military cases of 5G. This is due to the differences in requirement and deployment.

Table 1: 5G Military Use-Cases Based on Key Functional Parameters

Technology Attribute	**Source**	**Military Use**
Enhanced Mobile Broadband **e(MBB)**	**3GPP**	Voice & data connectivity for all personnel & HQs, Logistic nodes.
Ultra-reliable Low Latency Network – (**UrLLC)**		Time critical networks – Command posts, Joint Operation Centres, Special operation forces, Hypersonic Weapon Control.
Mass machine type Communication- (**mMTC)**		V2X cases, Autonomous Systems, UAV Swarms, Robotics.

Note: The Next Generation Mobile Network or NGMN has also defined nearly eight use-cases of 5G.

Source: Annotated by Author

Military networks does not have fixed infrastructure like civil networks. As the situations develop on-the-fly, the networks also needs to be modified accordingly. Thus, the resources are required to be flexible over land, air and sea. Wide area coverage is required, however owing to secrecy issues, reliance on civil network may not be feasible. More importantly, military communication mainly happens within a contested EM space/ spectrum. Therefore, the network also has to survive extreme environment and rough use in the battlespace.

One also have to note the specific requirements of the various elements of services as the hardware, although modular, need to be same for land and sea forces as also the Air Force and the Navy. Multiple information has to be processed and thereafter passed on to the decision makers. Jointness & theaterisation imposes further challenges in terms of commonality of the protocols and equipments needed. There will be heavy reliance on ad hoc networks [d] or MANETs which will be time based depending on the tempo of operations involved. Spectrum and energy efficiency will also play a key role in 5G militarisation. Key performance indicators have been covered in **Figure 9**.

Various architectures have been envisioned in the work by Liao & Ou titled *5G Military Application Scenarios and Private Network Architectures* [14]. To summarise, low operation

[d] A wireless ad hoc network (WANET) or mobile ad hoc network (MANET) is a decentralised type of wireless network. The network is called as an ad hoc because it does not rely on a pre-existing infrastructure, such as routers in wired networks or access points in managed (infrastructure) wireless networks. An on the fly/ spontaneous network.

and maintenance cost can be incurred when the same network infrastructure is shared between the public and military, with slicing done to create a private 5G network. Thus, there is coexistence with a tradeoff for speed. Hence, logistics or routine messages/ correspondence may rely on such a topology. A second case can be with a separate frequency band allocated for military use that is a clean separation between the public and military network can be executed and used for high secrecy operations and subsequently meshed with land/sea/airborne infrastructure. However, with spectrum being a scarce resource, this decision will be a tough call. There can be other permutations of the scheme by including or removing the control plane & user plane interactions based on security requirements etc.

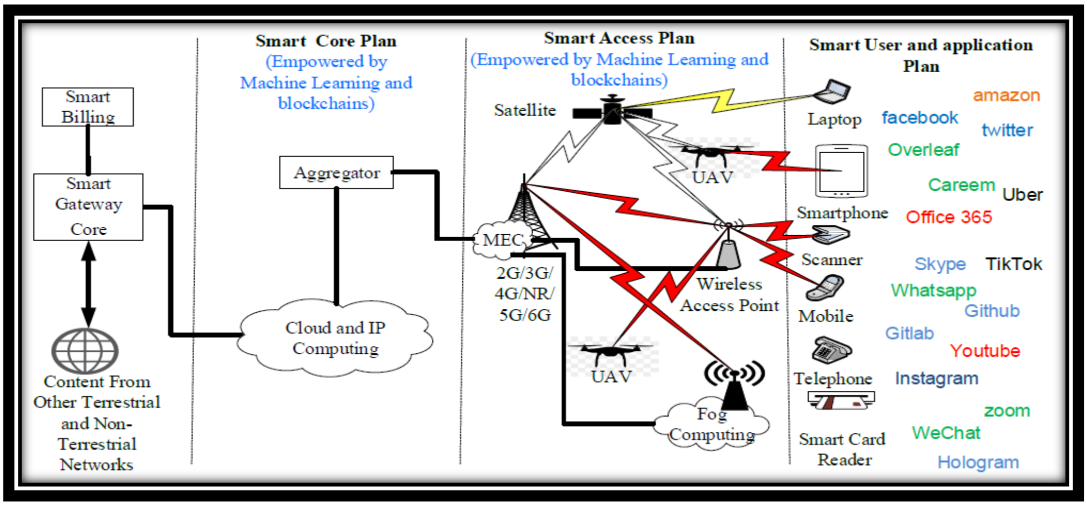
Figure 9: Key Performance Indicators & Connotations

Key Performance Indicator	Connotation	Value
Priority	According to the priority assigned by the importance of military tasks, the priority of 5G network slice scheduling resources can be determined, which can be dynamically adjusted in real time according to the task process or battlefield environment	High: Battlefield real-time confrontation tasks Middle: collaborative training tasks Low: logistics equipment support tasks
Delay	Specifically, it refers to the end-to-end delay, the time when the terminal sends data to the other end to receive data when performing military tasks. The remote control service of the unmanned combat platform needs higher requirements.	The unit is ms. 5G end-to-end delay can be up to 1ms.
Reliability	Under the specified conditions and functions, it can provide trusted services for specific military tasks and determines the trustworthiness of the network during the execution of military tasks.	Weapon strike: 99.999% Command and control: 99.9% Service support: 99%
User rate	It is the guaranteed user speed under the actual load. The user not only includes the warfighter, the equipment support personnel, but also includes the radar and other sensors, missiles and other weapon platforms	The unit is bps. 5G peak rate can reach 20gbps under specific conditions
Mobility	It refers to the maximum mobile rate that can be supported under specific QoS and seamless transmission conditions. The target is for high-speed moving objects such as aircrafts, ships and land combat vehicles. 5G focuses on overcoming Doppler shift and frequent switching	High: >200km/h Medium: 2-200km/h Low: <2km/h
Connection density	It refers to the total number of online terminals that can be supported per unit area. Online means that the terminal is communicating with a specific level of OoS, mainly for the battlefield or military material support scenarios where massive sensors are distributed and interconnected.	High: >104/km2 Medium: 100～104/km2 Low: <100/km2
Security classification	It refers to the security level of military application. Services are logically isolated in a physical network according to the security level .	High: Classified Medium: Secretive Low: Unsecret
Energy efficiency	It refers to the amount of data that can be sent and received per unit of energy consumed at the network side and terminal side. And it is mainly for the needs of the Internet of things such as Offshore operation s and landing operations far away from the command posts.	High: Weapon sensor sensing Medium: Battlefield Situation Low: Remote control

Source: J. Liao and X. Ou, "5G Military Application Scenarios and Private Network Architectures"

What also needs mention is the development of terrestrial and non-terrestrial networks (TaNTIN). The military use of 5G will also encompass use of usual multimedia services apart from voice and data calls. An example of TaNTIN has been shown in the **Figure 10** which encompasses the use of technologies such as edge computing, AI, blockchain & network virtualisation techniques.[15]

Figure 10: An Example for TaNTIN Implementation



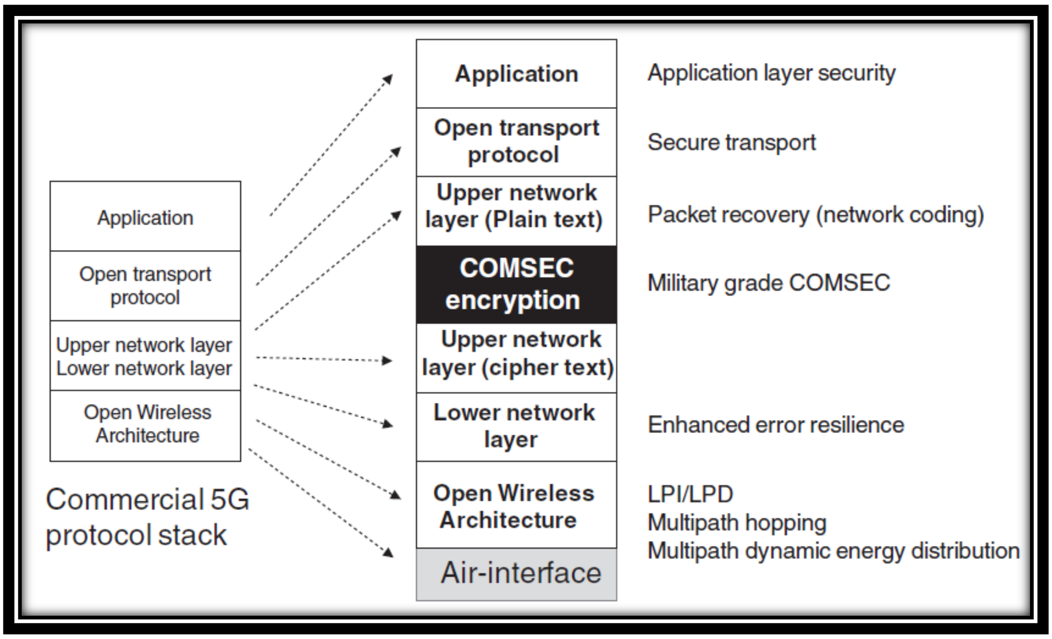
Source: Akhtar, Muhammad Waseem, & Hassan, S. A. (2021). TaNTIN

Apart from these networks, progress will also have to be made in cases of wearable devices and the impetus will fall on 'smart-soldiers', who are capable of taking the defence innovation industry by storm.

When we talk of security, then there is a need to convert the existing security stack for use in civil to militarised stack with added layers of security. The Open Radio Access Network[e] (o-RAN) will be of immense use here but however needs to be tweaked a little to suit the layers of security as desired with military grade protocols **(Figure 11)**. [16]

[e] Open RAN is a term for industrywide interface standards that allow RAN equipment and software from different vendors to communicate. The top two organisations working on open RAN are the Telecom Infra Project and the O-RAN Alliance.

Figure 11: Security Stack for 5G – A Representation



Source: George F. Elmasry, "DSA and 5G Adaptation to Military Communications"

To adapt the system for military use, the aspect of multi-user MU-MIMO can be leveraged along with anti-jamming waveforms (an aspect to be dealt with separately). Advantages of low probability of intercept can be achieved while also achieving redundancy in networks using mesh-routers.[17]

Recommendations and Suggested Organisation

The militarisation of 5G for the forces should be rolled out based on a 'National Strategy for 5G Implementation'. While the tenets of this strategy can be deliberated later, recommendations can be made based on the global military use-case scenario. *Atmanirbharta* or self-reliance is key, however, it cannot be at the expense of a temporal loss as this technology, like any other, is time sensitive— the earlier we graduate to it, easier will it be to keep pace for the fusion and proliferation with other 'sister technologies'. Swarming UAVs, virtual reality simulation & training, real-time ISR, distributed command & control, and smart warehousing facilities, are only the start.[18]

- ***Policy formulation.*** It is important to publish a policy with guidelines along with a roadmap for implementing 5G. We should aim to leverage the already existing 4G/ LTE infrastructure to speed up the adaptation of this technology. It is only after we adopt the technology in daily use, we will be able to tweak it for other purposes. This policy framework will require SMEs in addition to the stakeholders from all agencies in equal measure. There are bound to be strategic spin-offs in terms of developing such technology which can later be extended to countries in the African continent.

- ***Innovation and Development.*** Simultaneously, innovate and develop systems with an aim to develop a private 5G network for the forces. This would require immense innovation for developing critical hardware, exploring new technological frontiers, engaging the security aspects and allocating budgetary resources to bring it to fruition. The 'iron-triangle' of industry-academia-military partnership is inescapable here. As brought out earlier, since technology is time sensitive, therefore, it would be good to go for commercially-off-the-shelf (COTS) equipment or technology, that has been acquired as a result of inter-governmental negotiations. India is a strong harbor of software talent. Partnerships with countries looking forward to such collaborations should be welcome. Chip manufacturing, where India is presently lagging needs to be developed at an accelerated pace. Cooperation with Israel for 5G technology should be thought of as both the countries share strong innovation base. With the ousting of Huawei and the likes, there is an 'inescapable need' for indigenous R&D to develop hardware and software and thereafter cater to rolling out of 5G in the near future.[19]
- ***Validation of Technology.*** Validation of technology should be the next step which would result in developing test-beds. As covered earlier, the military use-cases will require testing before being accepted as military grade. 5G, when combined with IoT, an automated supply chain, and AI, can enable Just-in-Time (JIT) logistics— a system in which logisticians can ascertain stock levels while still accounting for fluctuations in demand. How the various agencies can participate towards testing and validation of technology is suggested as under : -
    - Military College of Electronics & Mechanical Engineering and Combat Vehicles Research & Development Establishment for V2X[f] and smart logistics as also for robotics/ IoT and antenna design implementation. Armoured Centre College and School with Army Service Corps College can also be stakeholders for tests of V2X & ProSe.

[f] V2X or vehicle-to-everything is a system that enables cars to communicate with compatible networks and devices – including other vehicles and pedestrians – as well as road systems, traffic controls and other infrastructure.

- Military College of Telecommunications Engineering and Private Enterprise for backbone access technologies, Edge Computing and AI.
- Army Air Defence College for testing hypersonic weapon control with M/s BAPL.
- Any big cantonment areas (with different geographical location and characteristics) for 5G roll-out of towers to validate the data rates/ throughput. The US forces too have 'sandboxed' bases which are being used extensively to try out the technology. Companies (domestic alternates to China) have been invited to test their products for military specific applications. This also supports the military-industry collaboration, that is being stressed upon world over.[20]
- Integrate DPSUs such as DRDO/ C-DAC for Scientific Analysis Group/SAG encryption/ QRNG[g]/ Quantum interface and secrecy aspects of the protocol.
- CAIR may look at reviving the smart soldier system initiative for wearables as well as sensor to shooter links.
- A Central Ordnance Depot to be a test bed for smart warehousing. Simultaneously, Joint Logistic Nodes can serve as test-beds for joint logistic operations testing. The greater bandwidth offered will be able to accommodate up to a million sensors within a square kilometre at very high throughput. Small electronic tags will also enable real-time asset visibility across the theatre.
- Industry can participate in the testing of non-terrestrial links with ISRO.

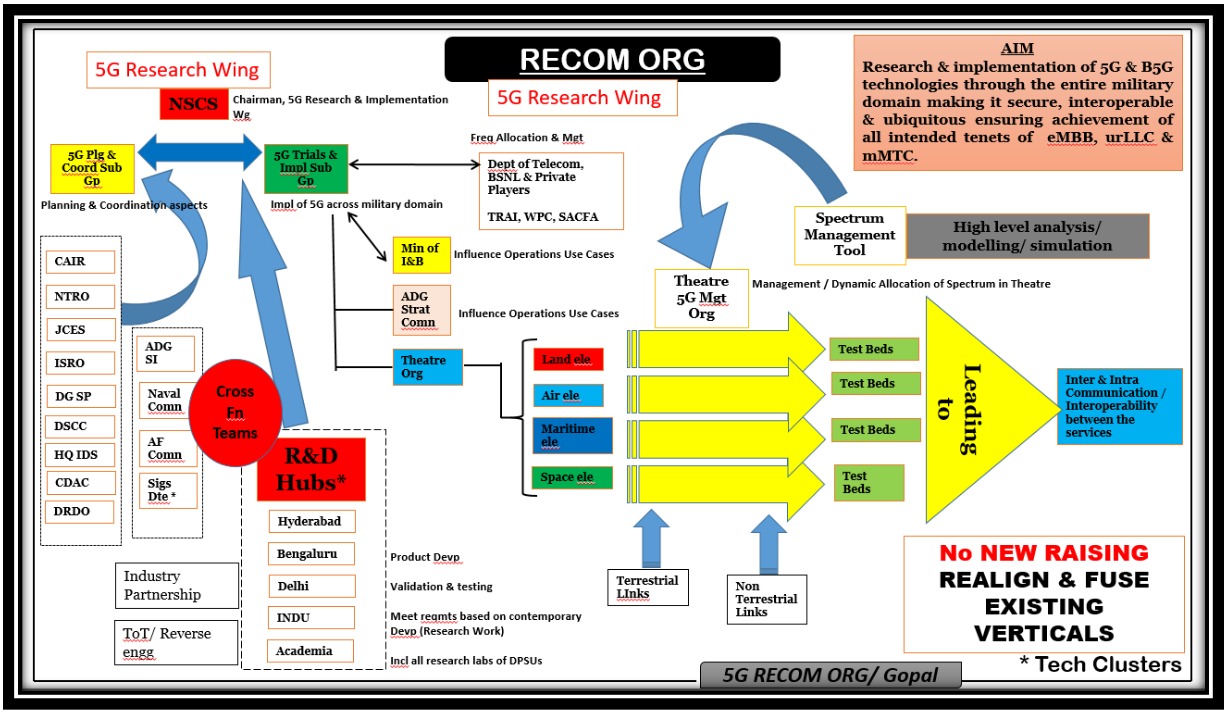
- ***Securing the network.*** This will be one of the most critical aspects of the militarised 5G network. Penetration testing & performance in an electronic warfare degraded environment is essential. Development of protocols, waveforms, incorporating AI & ML as well as leveraging the technologies of MIMO/ MU-MIMO, adaptive beamforming etc., will be encompassed as part of this tenet. Role of DRDO and other such agencies, in developing quantum encryption, will be of great help for India.

[g] Quantum Random Number Generator (QRNG) generates perfectly unpredictable random numbers, derived from a quantum source and delivered at speeds needed for commercial applications, to ensure the strongest level of encryption.

- ***Development of non-terrestrial technologies.*** This is of extreme importance for the forces due to the inherent nature of warfare which is dynamic by nature and extends to multiple domains in today's scenario. Reliance on satellites in LEO/MEO, pseudo-satellites and UAVs in extending range of communication is considered as increased dependence.
- ***Implications of 5G on MANETs.*** Quick transfer of data will lead to better control of unmanned systems. Real-time command & control architecture will develop as a result of this technology.
- ***Flexibility in Spectrum Sharing.*** The proposed National Strategy should aim at achieving a spectrum dedicated for military use while keeping backbone services/ integrated access backbone shared for non-critical operations and exclusive for sensitive areas. The associated radio frequency elements, form components and circuits to antennae, have to be designed to keep pace with the envisaged requirement.
- ***Developing B5G.*** Developing B5G and 6G technology with focus on mm-wave communications is an important step. Although the architecture in terms of circuit design, infrastructure being far greater due to line of sight issues & methods to obviate atmospheric attenuation will be associated problems, we must concurrently look at the technologies to exploit the tera-hertz segment. Civil/ Industry should take the lead— however, with Government support. Budget should be allocated for pilot projects and technology demonstration hubs should be constructed. Increasing the funding under R&D, will augur well for a subsequent 6G rollout.
- ***Identify and Diversify.*** Identify and diversify the suppliers of equipment to be utilised in 5G implementation to prevent monopolisation. Systems which are scalable and interoperable are to be made. One cannot let-go of the legacy systems already in use.
- ***Develop a supply chain.*** There is a need to develop a robust supply chain mechanism which is attributed by experts in the field; strong technical skill-set, testing labs, resources to augment the development of the technology. Academic institutions and industries can also be included as important stakeholders.

National Strategy should view the aspect of 5G under the heads of implementation, cyber security, in-house facilitation and lastly global impact. How these recommendations can be implemented & by which agencies will require deliberation. However, we must remember that instead of a 'turf-war' or 'fear of being left out', a fast-track approach will result in greater benefits. A suggested model of implementing the above cited recommendations is suggested schematically in **Figure 12** below. As always, new technologies make way for newer verticals which emerge from the fusion of already existing 'silos'. The aim of the model suggested here is to re-mould the existing verticals and optimise the overall system. This model is based on the importance that needs to be given to the concept of 'theaterisation' as we are in the process of implementing the changes leading to 'jointness' in operations which are going to be the need of a multi-domain battlespace.

Figure 12: Proposed Organisation to Manage 5G Research



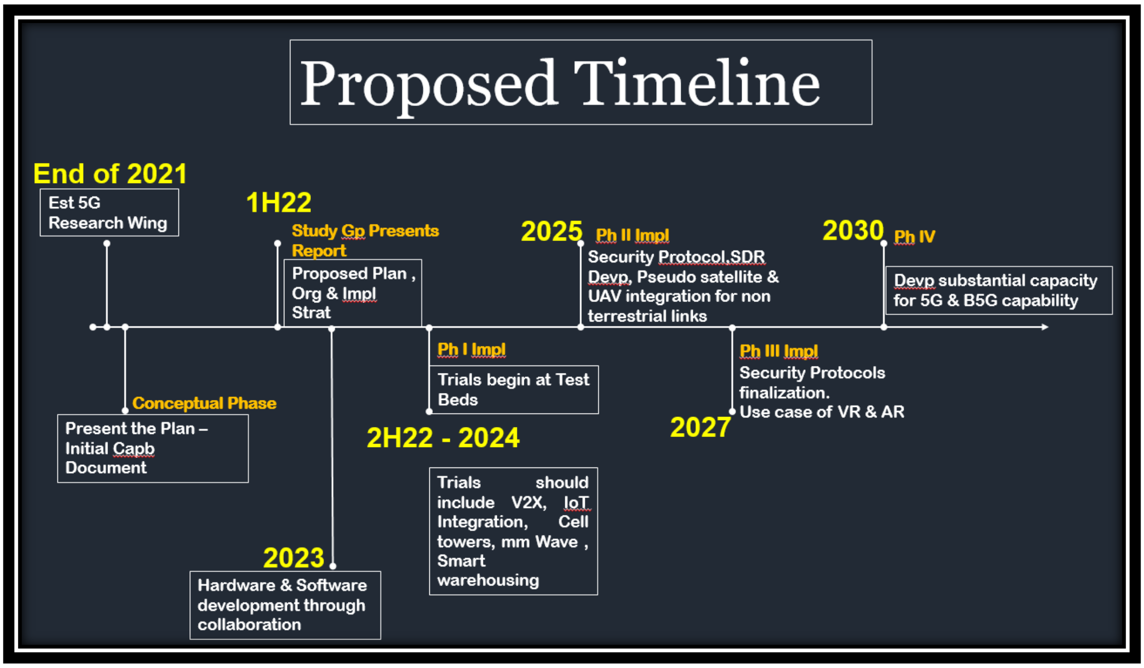
Source: Annotated by Author

Implementation Timelines: Putting Theory to Practice

'Accelerate, operate & innovate' will be the mantra for execution of 5G in military. There is an urgent need to graduate onto this technology to not only keep pace with changing times, but also to leverage the potential offered by this budding technology.

A proposed ten-year time plan to implement the 5G technology across the forces is shown as per **Figure 13** below.

Figure 13: Proposed Implementation Timelines



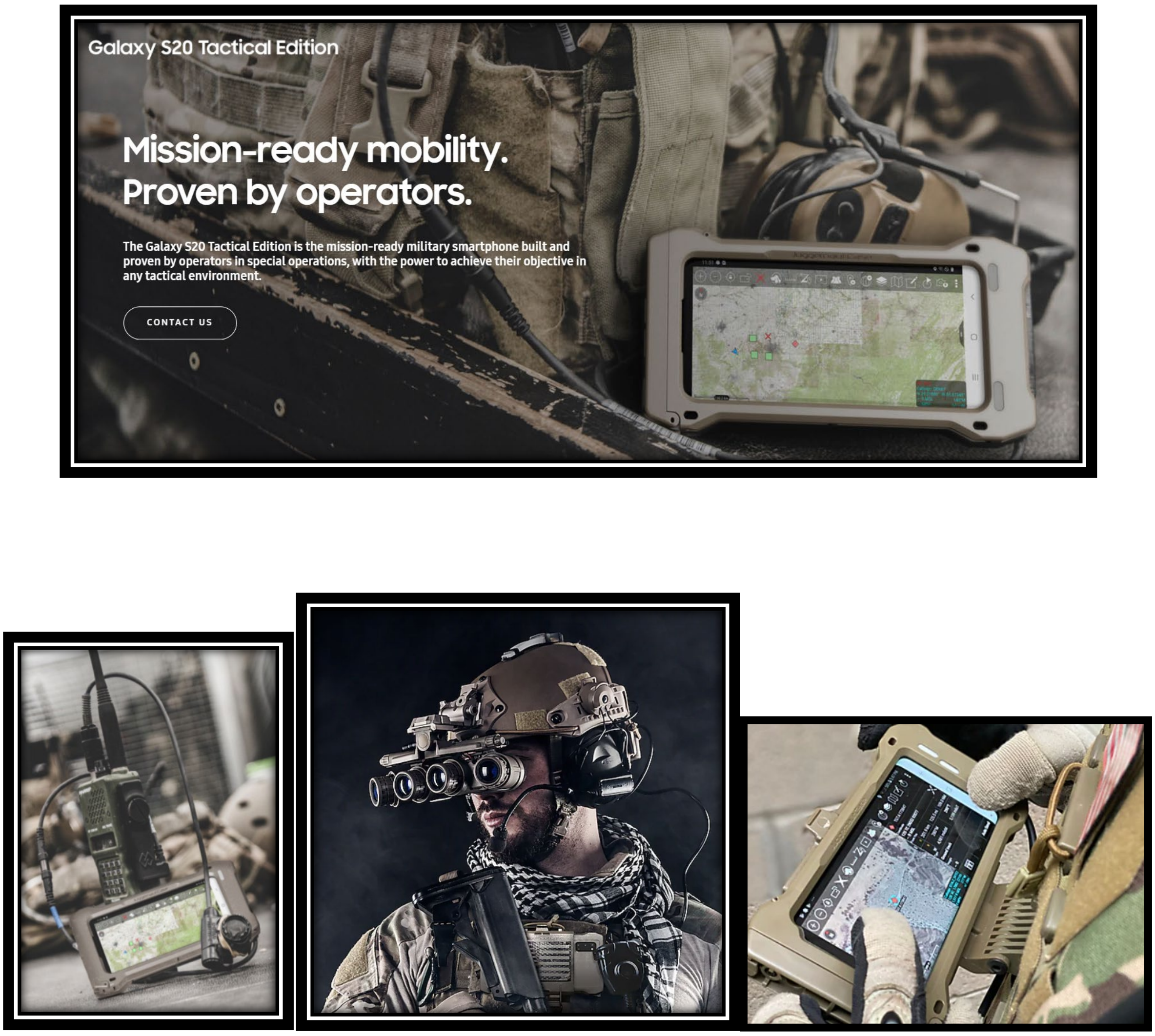
Source: Annotated by Author

Conclusion

5G holds the promise of ubiquitous high-speed data connectivity; vastly improved ISR; fast and secure command and control; more efficient logistics; swarming unmanned vehicles; and wide use of virtual reality and augmented reality. The all-pervasive nature of 5G has been understood by the Indian Armed Forces.[21]

It is this technology which will see the amalgamation of better spectrum usage with disruptive technology such as unmanned systems, IoT and AI. China have already invested heavily in AI, undersea cables and 5G infrastructure. We need to follow suit.

Figure 14: Samsung Tactical Handset (S20) – 5G enabled Radio for the Forces



Source: Samsung Website

5G aims to create an omnipresent ionosphere where data from sensors, targeting surveillance, and signal intelligence are persistently available. With advances in edge computing, the mission critical data will enhance manifold the battlefield transparency as well as aid commanders in a more responsive decision making process on the fly.

End Notes

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