LOCKHEED MARTIN

NTIA 5G Challenge
Notice of Inquiry Response

Lockheed Martin Corporation

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Executive Summary

An NTIA-sponsored open 5G stack Challenge has the potential to accelerate the development of a DoD-centric open 5G ecosystem that fosters market competition and drives innovative solutions for DoD missions via critical DoD 5G capability enhancements. To succeed, the NTIA needs to structure such a challenge to generate clearly defined standards for which compliance can be readily verified and that drives dual use commercial/government solutions to incentivize broad commercial industry participation in the future of the ecosystem.

In this whitepaper, Lockheed Martin Corporation (LMCO) provides recommendations for structuring a Challenge to create a foundation of DoD open 5G standards that optimally decompose the 5G stack to support DoD-required 5G enhancements. NTIA should aim to meet the following goals with the Challenge to incentivize and maintain the widest market participation, encourage innovation, and provide explicit targets to developers for a well-defined path to DoD and US government (USG) customers.:

- Ensure DoD/US Government (USG) 5G standards are aligned with those promoted by the O-RAN Alliance, Telecom Infra Project (TIP), and other open standards groups to guarantee USG market share access for commercial providers.

- Include RDT&E protocol design aligned to the DoD open 5G standards as part of the Challenge

- Create and publish a clear timeline/schedule under which the NTIA will align, verify, and validate open stack standards for 5G features applied to DoD-unique use cases.

- Strive for a 5G stack decomposition and interface standardization at similar functional granularity as current 3rd party IP single-vendor marketplaces. The DoD open 5G architecture should have functional blocks that enable maximal flexibility to open access to a larger developer community.

Finally, The DoD has unique capability needs that the standards must enable, including hardened cybersecurity, enhanced network resilience, and DoD mission-specific functionality that commercial 5G standards cannot meet alone. The NTIA should structure the challenge around key multi-domain mission threads designed by the DoD to expose core areas of the stack for standardization based on operational dependencies and inform a prioritized approach to decomposition. Here, experienced technology integrators like LMCO with intimate knowledge of diverse DoD mission sets and high fidelity end-to-end (E2E) testing capabilities will be essential partners for NTIA and the rest of the 5G community to amass an open ecosystem that DoD can dynamically leverage to accelerate the pace of 5G wireless technologies.

I. Challenge Structure & Goals

A. How could a Challenge be structured such that it would take advantage of DOD's role as an early U.S. Government adopter of 5G technology to mature the open 5G stack (i.e. interfaces are published) ecosystem faster, encourage more participation in open 5G stack development including encouraging new participants, and identify any roadblocks to broader participation?

For the NTIA to secure participation in an open 5G stack challenge, it should first drive alignment with established industry groups to promote dual government and commercial applications of technology. There are a diverse set of open RAN communities that are making strides in open 5G stack development including major contributors such as the O-RAN Alliance and Telecom Infra Project (TIP). These organizations are attempting to drive alignment of functionality as defined by 3GPP and the European Telecommunications Standards Institute (ETSI), but NTIA/DoD-driven alignment provides an opportunity to drive faster advancement. For example, the DoD could benefit from mobile edge standards that enable convergence of applications within the 5G infrastructure stack. However, as noted in a recent article, "Mobile edge computing is fragmented because cloud providers, operators, and vendors are increasingly striking partnerships and approaching the opportunity from their own vantage points and for their respective interests."[1]

The NTIA can foster collaboration across standards organizations from the start and encourage broader participation with liaison agreements to reduce development of conflicting standards and ensure technology providers will have diverse markets for their technology. The USG should ensure DoD next-generation mobility ("NextG") standards are aligned with those promoted by the O-RAN Alliance, TIP, and ETSI to guarantee USG market share access for commercial providers as well as incentivize continued development of commercial product components compliant to these standards.

The NTIA can also reduce risk and encourage participation by aligning the priorities and timeline of open 5G stack standards development with the anticipated rollout of US Government use-cases and desired features, for example under the OUSD 5G to NextG initiative. Aligning of standards development and use case/feature needs timelines can assure broader industry participation by establishing a longer business horizon for investments beyond immediately accessible experimentation efforts. Furthermore, open standards development by an open consortium model such as Sensor Open System Architecture (SOSA) enables participation by the full industrial complex, not just those executing under contract. Some notable use cases/features for consideration include:

- Full support for eMBB use cases at certain frequency bands (e.g. C-Band and CBRS band)
- Support for mMTC (specify band/bandwidth) for NB-IoT type of service on 5G
- Support for non-terrestrial networks (NTN) (both Transparent and Regenerative)
- Support for seamless transition from between NTN and terrestrial network (TN)
- Acceleration of Device-to-Device (D2D) network standards and implementation

[1] https://www.sdxcentral.com/articles/news/common-edge-computing-framework-remains-a-longshot/2020/12/

- Echelon-tailored multi-access edge compute (MEC) deployment
- Secure Network Slicing
- Aligned zero-trust architecture models and cybersecurity accreditation processes
- Voice over NR (New Radio)

Perhaps most importantly, to encourage participation from diverse participants, the NTIA should structure the initial challenge goals around clearly defining critical DoD-unique functionality, timelines, and validation/verification requirements for DoD compliance with the open 5G stack standards. This focus has two primary benefits: 1) it ensures participants that their technology investment would have a clear path to the DoD/USG-customer base, and 2) it emphasizes proactively addressing security and deployment risks inherent in modular solutions sourced from multiple participants, including international participants. The DoD can mitigate these risks early by taking advantage of industry technology integrators like Lockheed Martin Corporation (LMCO), with expertise across a variety of DoD missions as well as proven test and integration capabilities, to broker hardened solutions between the open 5G stack technology providers and USG communities. Early in the Challenge, NTIA should work with DoD and industry partners like LMCO to scope a set of use cases based on critical mission threads – a sequence of end-to-end activities that take place to accomplish the execution of a system of systems capability (e.g. targeting and fire control). This scoping activity will allow NTIA and DoD to assess the core operational stack dependencies and corresponding opportunities for stack standardization. The NTIA should then publish a prioritized schedule under which the DoD will align, verify, and validate open stack standards for 5G features applied to these DoD-unique use cases.

To structure this 5G Challenge, the NTIA can also take lessons from previous DoD attempts to leverage commercial technologies while advocating for a modular open system approach (MOSA). For example, the Future Vertical Lift (FVL) initiative began in 2009 with a goal of finding the next generation rotorcraft, a core component of which was Mission Systems Architecture Demos (MSAD) to develop & demonstrate a rich set of capabilities built upon a Joint Common Architecture (JCA). The JCA is critical as the initiative simultaneously seeks to develop next generation airframes, concepts of operation (CONOPS), and mission system requirements; thus, requiring open mission stack definition via MOSA. The MSAD effort coordinated Government and Industry participants using Model Based Systems Engineering (MBSE) and test-driven development to evolve the community's ability to deliver modular mission systems agnostic of hardware platform. The structure of the MSAD included 1) establishment of the JCA standard(s); 2) model-based demonstration of the JCA logical interfaces under an Architecture Implementation Process Demonstration (AIPD); 3) a series of MSAD Capstone demos for full mission system architecture operation and model validation (ostensibly verifying future vendor solution interoperability). The government through efforts like FVL MSAD has greatly advanced the state of MOSA within the DoD, increased the amount of participation by solution vendors, and stimulated evolution of open standards such as the Future Airborne Capability Environment (FACE) and SOSA Reference Architecture, both managed by The Open Group.

B. How could a Challenge be structured to focus on the greatest impediments to the maturation of end-to-end open 5G stack development?

We highlight the following critical impediments to the maturation of end-to-end open 5G stack development that the NTIA should mitigate in structuring a 5G Challenge:

1. Open 5G stack solutions often lag the functionality defined in the 3GPP standards. For example, current Open RAN software lacks much of the functionality defined in 3GPP Releases 15 and 16.
2. Compliant solution deployment options for hardware and software can be limited, restricting participation from a broader range of companies

To mitigate impediments 1 and 2, the NTIA could structure a 5G Challenge with the goals identified in Question A – clearly defining requirements for functionality and timelines according to DoD's needs. These requirements should include flexible deployment options for hardware and software solutions: e.g. private/government centralized cloud, edge cloud, bare metal deployment, indoor or outdoor deployment, small cell or macro cell deployment.

3. Full end-to-end (E2E) interoperability testing capabilities are unavailable.

Mature E2E stack development requires full E2E interoperability testing yet is currently lacking in industry open stack efforts. Again, a NTIA 5G Challenge would benefit here from a goal to partner with experienced technology integrators like LMCO to design and execute thorough interoperability testing and E2E validation/verification testing protocols (including the 5G Core) in parallel to the open stack development that meets the coordinated needs of the entire DoD.

4. Decomposition of stack architecture in open 5G stack solutions does not optimize functionality, innovation, or upgradability

To overcome the impediments inherent in the current 5G ecosystem of competing interests, the USG/DoD must use its single market power to harmonize an end to end open NextG mobility standard. It is critical for a NTIA open 5G stack Challenge structure to decompose the stack appropriately to achieve 1) the optimally flexible architecture required for DoD use cases beyond the capabilities enabled by the commercial 3GPP standards, e.g. capabilities for different 5G RAN layer splits for different deployments and DoD-unique stack modifications, and 2) participation from the widest diversity of commercial 5G ecosystem developers at the lowest cost and flexibility for the DoD while allowing developers to maintain control of their critical intellectual property within the boundaries created by the open interface standards. Here we note the important differences between the DoD's needs vs commercial Mobile Network Operators (MNO). First, the commercial world has decomposed the logical elements and interfaces as much as necessary to support new commercial deployment models but the DoD will require further decomposition and interface standardization as modified functional blocks will be required for 5G-derived technologies to operate in highly contested RF and cyber environments (e.g. modified layer 1 waveform processing). Second, MNOs maintain proprietary E2E network implementations while supporting development of open standards for subsets of the network (e.g. ORAN), while the DoD must drive an E2E infrastructure standard to reduce the cost of

acquisition, innovation, flexibility across various mission needs, and ultimately maintenance of what will hopefully support a DoD-hardened hybrid (public/private) wireless infrastructure.

Current commercial market dynamics between MNO and the small ecosystem of Network Equipment Manufacturers (NEM) then, are partly responsible for the relatively slow and piecemeal growth of open standards in the 5G domain as solution providers are not dependent on standardization to deliver commercial solutions. In addition to competing commercial interests, there is also a dizzying array of organizations attempting to influence adoption on behalf of their consortia. The DoD can best position itself by acting as a coordinated acquisition community with the willingness to maintain a single E2E architectural framework with defined set of adopted commercial standards releases. This acquisition model has been successful on the FVL initiative and the vision is not unlike that initially laid out in 2016 by PEO Aviation in Figure 1.

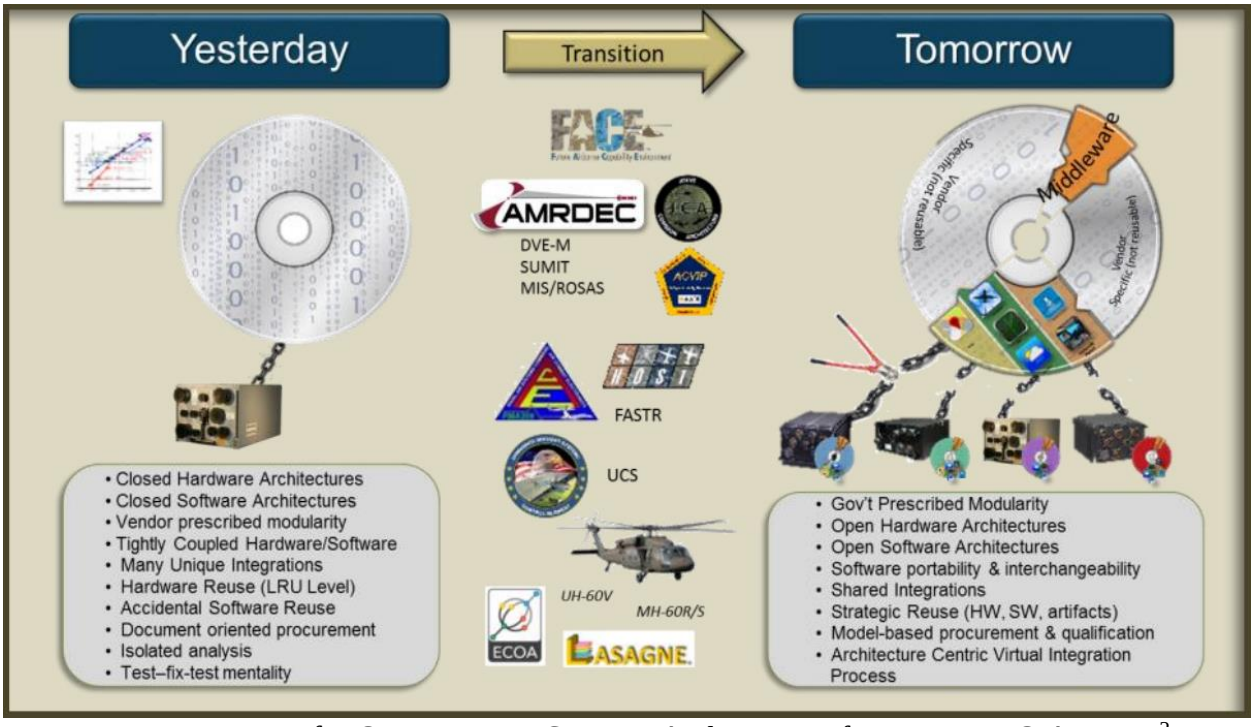

Figure 1 - Vision for Open Mission Systems Architectures from FVL PEO Aviation[2]

Furthermore, decomposing to standardized functional interfaces opens access to a larger developer community where innovation may be possible in smaller portions (i.e. not requiring larger infrastructure to demonstrate innovative solutions). This innovation model implicitly exists now within 3rd party IP marketplaces such as those run by Xilinx and Intel where companies provide low-level implementations of 3GPP functions. This low-level IP is independently acquired and integrated by radio vendors but is not typically developed to open interface standards and therefore is not interchangeable with future innovative solutions without significant cost.

[2] Kretzschmar, Rich, "Improved Turbine Engine Program (ITEP), Future Vertical Lift (FVL), Presentation of Improved Turbine Engine / Future Vertical Lift Project Office, 10 June 2016.

C. What should be the goals of a Challenge focusing on maturation of the open 5G stack ecosystem? How could such a Challenge be structured to allow for the greatest levels of innovation? What metrics should be used in the assessment of proposals to ensure the best proposals are selected?

Many of the optimal 5G Challenge goals and structures to promote innovation have been previously mentioned in our answers to questions I.A. and I.B. For example, the NTIA should establish clear functional goals for the open 5G stack as well as requirements and timelines coupled with adequate E2E interoperability testing. These goals could be achieved with a small initial systems engineering phase to help NTIA identify and prioritize the necessary decomposition and features to support unique DoD use cases.

Generally, to the ends described here and in Questions I.A and I.B, the open 5G stack Challenge goals could best mirror the stated goals of SOSA and MSAD:

1) **Open**: develop and demonstrate a "vendor and platform-agnostic open modular reference architecture and business model" that further decomposes functionality to the level required by the DoD, such as exposing standard interfaces for the L1 interfaces
2) **Standardized**: enable an E2E ecosystem by fully defining "software component, hardware element, and electrical-mechanical interface standards"
3) **Harmonized**: maximally "leverage existing and emerging open standards scope" by developing a single E2E standard defining how/where commercial standards are adopted
4) **Aligned**: provide business as well as functional guidance to ensure the framework is "consistent with DoD acquisition policy guidance"
5) **Cost-effective**: enable "affordable C4ISR systems including lifecycle costs" by demonstrating the open 5G stack on multiple 3rd party hardware platforms (e.g. x86, GPU, ARM) (in alignment with DoD DevSecOps efforts like PlatformOne)
6) **Adaptable**: validate the framework is "rapidly responsive to changing user requirements" by defining multiple Proof of Concept (POC) deployments for the DoD that require different compositions of the open 5G stack (to include increased security and resilience features) (in alignment with containerization and deployment models of DoD efforts like PlatformOne)

In addition to the goals above, the Challenge goals should also include a focus on **"Innovation"**, in fostering the breadth and diversity of available, interoperable solutions and **"Speed"** to allow the developer ecosystem to rapidly develop and deploy advanced capabilities to support national and DoD objectives for US industry competitiveness. Open 5G stack Challenge proposals should not focus on assessing individual component performance metrics which are often domain specific and are mostly captured within 3GPP standard already. An open 5G stack Challenge should favor proposals that: 1) foster achievement of an open reference architecture that enables innovation for the unique performance requirements of DoD use cases (e.g. security and resilience), and 2) include consideration of metrics evaluating the ability of the open 5G stack to support E2E deployments in the various POCs (along with E2E testing procedures to adequately evaluate these metrics):

1) **Deployment Speed**: time required to deploy all open 5G stack components onto each of the target system environments. Should be evaluated as necessary independent of host

platform to understand the impact of the vendor implementation vs the impacts unique to deploying on a given hardware type (e.g. x86, GPU, ARM).

2) **Open Stack Overhead**: how much computing resources are required to execute components exclusively supporting open interface aspects, vs what would be expended on a proprietary bare-metal implementation. E.g. additional compute cost of middleware, gateways, and other open interface components.
3) **Interface Coverage**: how much of the E2E and adopted commercial standards are supported by the solution. Just as commercial solution vendors only implement portions of the 3GPP standards that are commercially viable, there might be aspects of the open 5G stack which ultimately don't get implemented. This metric and percentage mapping to interfaces should be tracked to inform future progression of the E2E standard.
4) **Conformance Coverage**: how many of the commercial standard Conformance tests has the solution passed and thus achieved Certification for. It may very well be too costly to evaluate conformance, and thus out of scope for the Challenge, but the Conformance claims of each solution should be tracked and mapped to inform future efforts.
5) **Interoperability Coverage**: whereas Conformance addresses individual component compliance with each standard, Interoperability evaluates the capacity of multiple vendor solutions to operate together. Therefore, whereas Conformance testing is often done by individual solution vendors to obtain Certification, Interoperability testing is conducted by solution integrators to show end customers (such as MNO) that their higher tier solution operates as advertised. Given the higher order nature of the open 5G stack Challenge, interoperability testing and tracking of vendor-specific incompatibilities should be assessed.
6) **E2E System Test**: what is the performance of a specific composition of open 5G stack components when evaluated against 3GPP, operator, and POC Use Cases. E2E System Testing drives the need for automated and rapid deployment as well as an equally robust testing infrastructure. If these conditions can be met, the Challenge orchestrator should be able to obtain this rather large set of metrics against the potentially equally large set of solution permutations. If not, E2E System Testing may have to be the domain of a small subset of system integrators with fixed component compositions (this is how the MSAD was ultimately conducted).

D. How will the open 5G stack market benefit from such a Challenge? How could a Challenge be structured to provide dual benefit to both the Government and the open 5G stack market?

As referenced up front in response to question A, commercial market dynamics have created a scenario where open 5G stacks are not being developed fast enough for MNOs to rely on them and, in turn, MNOs do not necessarily require (despite preferring) open 5G stack solutions from their suppliers to create financial benefits that are often tied to time-to-market considerations. The DoD has a strong history of creating market forces for technologies that have dual-use application, most notably in the evolution of the FPGA over the past 3 decades. From an open standards perspective, militaries across the globe have been influencing and benefitting from the ANSI/VITA body of open embedded computing architecture standards since at least 1988. In fact, the SOSA consortia have recently influenced changes to the VITA standards based on required functional definition in sensor system pin allocations. We believe that an open 5G stack

Challenge by the NTIA has the potential to organize and focus potential solution vendors on a common architecture, reducing the burden on systems engineering on lower tier innovators, and thus accelerate commercial vendor ecosystem growth. In addition, government use cases already align relatively well with 5G commercial market use cases with the exceptions of some cases such as NTN and enhanced security requirements. By promoting standards that enable these exceptions to be designed as optional, yet standardized extensions, the NTIA/DoD can promote modularity, network flexibility and inter-operability. In addition, by collaborating with commercial MNOs, Network Equipment Manufacturers (NEMs) and 5G device suppliers, as well as traditional DoD industry players in the execution of the Challenge and the resulting architecture and interface standards, both the government and commercial industry stands to benefit from an open 5G approach.

II. Incentives and Scope

A. What are the incentives in open 5G stack ecosystem development that would maximize cooperation and collaboration, promote interoperability amongst varied open 5G stack components developed by different participants, and mature desired featured sets faster with greater stability?

A significant portion of a lower tier technology firm's costs are in evaluating the opportunity to provide a solution, and around the shaping of those solutions to an increasingly complex and potentially divergent mix of customer requirements. NTIA can enable competition to provide better solutions by influencing standardization at the same functional granularity as current 3rd party IP marketplaces run by single vendor. Then competition to provide better solutions could include a wider range of potential customers, expanding the opportunity space for 5G ecosystem participants. Nevertheless, NTIA/DoD standards must maintain a careful balance between too much standardization that may limit innovation and a level of functional granularity that enables the flexibility to cost-effectively adapt the stack as DoD mission needs evolve. This common architecture trade study should be a central goal of a focused Phase 1 for this Challenge.

Furthermore, the DoD customer base itself is a driving incentive that NTIA can offer to appeal to the widest array of business models and current IP evolving in the commercial 5G ecosystem as open standards develop. Consider the large number of vendors providing embedded solutions compliant to the ANSI/VITA standards: while the DoD is not the only customer, they certainly support the health of the ecosystem. Part of this is the assurance that comes with developing a solution to a standard adopted by a large acquisition community; an assurance that can be replicated in an open 5G approach in the commercial wireless community.

An E2E open 5G stack enables the development of robust conformance, interoperability, functional, and performance testing procedures. These procedures can then be automated and provided to stack developers for individual component evaluations. The NTIA, DoD, or another Government organization could subsidize open 5G stack testing in a way to promote efficient certification. There could be a fee for submitting components for testing but a commensurate monetary award for achieving successful certification of the submitted requirement. In this way, the organization can de-incentivize wasteful premature testing while incentivizing a community

of solution vendors who are seeking to badge their products with compliance to an Open 5G standard.

Finally, an E2E open 5G stack definition could potentially simplify business planning within commercial corporations so that they can roadmap development of their discriminators and not worry about exposing IP when integrating into new higher tier solutions. This is a very real concern within today's market as technology developers balance the risks of disclosing details of their solutions with protecting their critical IP.

B. Could a Challenge be designed that addresses the issues raised in previous questions and also includes test and evaluation of the security of the components?

As we described above in section I, for success an NTIA open 5G stack Challenge for the DoD must establish clear functional goals as well as verification/validation requirements aligned with E2E interoperability testing. For the DoD, with security a paramount functional goal, security test and evaluation could not only be included in the Challenge, it must be included. Once again experienced integrators like LMCO are best positioned to test and evaluate E2E integration, including compliance with DoD security standards.

Here we first distinguish from existing security testing already provided by Common Criteria Evaluation and Validation Scheme (CCEVS) and the National Information Assurance Partnership (NIAP) processes. The NIAP-CCEVS already provides for independent assessment of U.S. Government approved protection profiles of mobile devices, device management technologies, wireless networking equipment, VPNs, and a multitude of other enabling technologies. There are no profiles, however, for E2E wireless networking components such as would be required for the open 5G stack. Furthermore, the NIAP-CCEVS does not evaluate the system level integration of components, a composition which may create new vulnerabilities via operational dependencies not assessible in isolation of each component.

Therefore, independent security assessments of the components to a DoD-aligned open 5G stack can itself provide an additional level of incentivization by the development community. Cybersecurity breaches can cost firms hundreds of millions in legal fees, penalties, remediation costs, and other expenses while on average, market capitalization impacts can be in the billions. Solutions that can be badged with a DoD-aligned cybersecurity assessment therefore possess a highly valuable discriminator, much in the way that "MIL-STD-810" (or simply MIL-STD) has become synonymous with rugged equipment able to handle the harshest environments. While NIAP-CCEVS already carries this type of cachet, further expansion of the cybersecurity testing regime is paramount considering the ongoing and evolving threat of cyberattacks.

C. Could a Challenge be designed that would require participants to leverage software bill of materials design principles in the development of components for an open 5G stack?

To execute our recommended Challenge goals above to assess and define the ideal level of stack decomposition for standards development, participating development firms will necessarily have to submit their current software bill of materials (SBOMs) for consideration by a standards consortia. There have been prior DoD efforts in communication systems where the architecture

was overly defined at too granular level and the incentive for 3rd party development was overcome by the costs in adhering to an overly stringent specification. Since many 5G solutions are mature by this point, an SBOM-based joint architecting exercise should be able to reveal the proper level of decomposition with the minimal level of refactoring required.

Additionally, a significant portion of the development community already utilize the breadth of open source implementations for low-level open standards, such as those defined by the Internet Engineering Task Force (IETF). The SBOM will ensure full accounting of which software components are utilized and identify possible compliance issues at higher levels of the stack by utilizing obsolete open source components.

D. Many open 5G stack organizations have developed partial implementations for different aspects of an open 5G stack. What portions of the open 5G stack has your organization successfully developed with working code? What portions of the open 5G stack does your organization believe can be developed quickly (6 months or less)? What development support would best enable test and evaluation of the different elements of an open 5G stack?

LMCO engages with multiple 5G open stack communities including the O-RAN Alliance, 3GPP, and the Linux Foundation, to leverage 5G technologies within our existing programs and in partnership with the OUSD 5G-NextG initiative. LMCO is committed to Open Mission Systems (OMS) standards group, executive agent for the AEGIS weapons systems, and a Sponsor of the SOSA standards group. Harmonization of the effort under a DoD (perhaps "NextG") mobility standards body will accelerate all our efforts.

With regards to development support, as previously mentioned, a fully architected E2E 5G network testbed infrastructure would best enable test and evaluation of different elements of an open 5G stack. This capability will be especially critical early in the Challenge as levels of decomposition are considered and tested, to most accurately understand how changes at one stack level affect functionality up and down the stack. These evaluations will define verification and validation requirements and performance targets for potential solutions.

E. What 5G enabling features should be highlighted in the Challenge, such as software defined networking, network slicing, network function virtualization, radio access network intelligent controller, radio access network virtualization?

The open 5G stack Challenge should highlight existing O-RAN Alliance-defined use cases, but implemented E2E with wholly open stack components. This list of features currently includes:

- Enhanced Mobile Broadband (eMBB)
- Ultra-Reliable Low Latency Communications (URLLC)
- Quality of Experience (QoE)
- Quality of Service (QoS) based resource optimization
- RAN Slice Service Level Agreement (SLA) Assurance
- Traffic Steering
- Fixed Wireless Access

- Voice over LTA (VoLTE)
- Voice over New Radio (VoNR)
- Industrial Internet of Things (IoT)
- Private Networks
- E2E Sync
- Context-based dynamic handover management for Vehicle-to-Everything (V2X)

Additionally, the Challenge should include upcoming use cases for Non-terrestrial networking (NTN), RAN Intelligent Control (RIC) and Device-to-Device (D2D) networking.

III. Timeframe & Infrastructure

A. What software and hardware infrastructure will be needed to successfully execute this Challenge?

A DoD community open 5G stack standard and acquisition timeline will enable the development community to maximize investments in standards-compliant test & evaluation infrastructure. The community already invests in and utilizes continuous integration, continuous development (CI/CD) toolsets for software component development. However, the existence of a DoD standard to follow will enable the community to design additional standards procedures, processes, and hardware in the loop (HWIL) architectures to augment these existing software development toolsets. Multiple echelons of developer-hosted test beds will be essential in the development of component technologies. However, a fully architected E2E 5G network testbed infrastructure, capable of supporting conformance, interoperability, and performance testing will be required at joint community demonstration events for evaluation of the open 5G stack.

This infrastructure would include standard processors (e.g., x86, ARM CPUs and GPUs) that allow software from different sources to run on them with hardware accelerators such as FPGA/DSP/ASIC/GPU, etc., as well as standardized racks, chassis, power distribution, and cabling, and a cloud platform for virtualization. In addition, the challenge requires testing protocols that capture DoD mission needs and enable E2E evaluation of the effect on the entire 5G stack. To this end, demos intended to validate the open 5G stack should leverage DoD testing infrastructure investments in Live, Virtual, and Constructive (LVC) testing so that mission relevant scenarios can be executed while exercising the E2E components of the open 5G stack.

B. What is a reasonable timeframe to structure such a Challenge? Should there be different phases for such a Challenge? If so, what are appropriate timelines for each suggested phase?

As detailed below, LMCO recommends a phased approach (Figure 2) for the challenge (notionally FY21-FY23). The FY21 pre-standards phase should undergo a system engineering approach to identify, consider, test, and prioritize the decomposition strategies and features to most wholly capture the unique needs of DoD 5G use cases. Initial efforts should include mission system trades and initiate the Open 5G Stack development along with the DevSecOps framework to be used by the community.

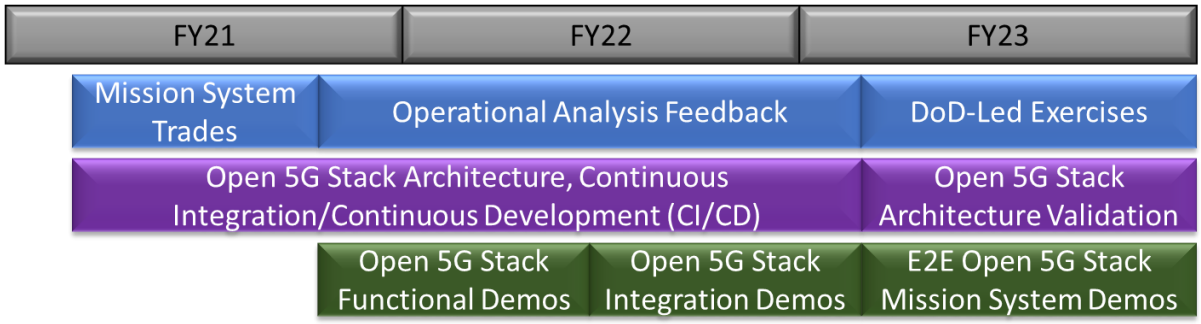

Figure 2 – Notional Open NextG Stack Challenge Phasing

The upfront mission system trades will set priorities on the open stack features to accelerate standard architecture development, though initial open 5G stack development can begin in parallel using mature features such as those included in current O-RAN releases. As the NTIA and DoD drive standards efforts and an acquisition timeline materializes, commercial standards development will likely harmonize with the effort, and as such, timing of newly prioritized features may accelerate commercial developer implementation. Therefore, the overall Challenge effort should be supported by continuous feedback from an operational analysis working group keeping track of progress, demonstrated capabilities, and evolving mission needs to adjust priorities as needed.

Demonstrations should commence as soon as possible, taking advantage of virtual demonstration capabilities enabled by software emulation, network modeling, and existing DoD operational analysis (OA) tools such as the USAF Advanced Framework for Simulation, Integration and Modeling (AFSIM). These Open 5G Stack functional demos should seek to provide feedback on the levels of decomposition provided by the current architecture baseline, as well as to uncover any challenges to integration. This feedback is essential in ensuring the decomposition is both sufficient to enable necessary enhancements while not being overly granular.

Towards the end of FY22, the Challenge should seek to demonstrate integration of the open 5G stack with candidate target hardware platforms provided by the commercial and tactical information technology ecosystem. These integration demonstrations are intended to show the portability of the stack amongst various hardware vendor solutions.

Concluding in FY23, the open 5G stack Challenge should provide validation of the approach to the DoD acquisition community, through both employment at existing OUSD demonstration exercises across the Services as well as Challenge specific Mission Systems demonstrations.