Broad Agency Announcement

FANG

Fast, Adaptable, Next-Generation Ground Vehicle
Tactical Technology Office
DARPA-BAA-12-15

December 5, 2011

- **Federal Agency Name** – Defense Advanced Research Projects Agency (DARPA), Tactical Technology Office (TTO)
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- **Anticipated individual awards** – Single award is anticipated
- **Types of instruments that may be awarded** – Procurement contract or other transaction
- **Agency contacts**

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I. FUNDING OPPORTUNITY DESCRIPTION

Background

DARPA's Adaptive Vehicle Make (AVM) portfolio of programs is aimed at compressing at least five-fold the development timelines for new complex cyber-electro-mechanical systems such as military vehicles.[1] Under AVM, DARPA is pursuing the development of several elements of enabling infrastructure aimed at radically transforming the systems engineering/design/verification (META[2] /META-II[3]), manufacturing (iFAB[4]), and innovation (vehicleforge.mil[5]) elements of the overall "make" process for delivering new defense systems or variants. Each of these infrastructure capabilities is largely generic, i.e., applicable to any cyber-electro-mechanical system. In order to exercise these capabilities at scale and in the context of a relevant military system, the present solicitation is aimed at producing FANG—the Fast, Adaptable, Next-Generation Ground Vehicle—a new heavy, amphibious infantry fighting vehicle (IFV) with functional requirements intended to mirror the Marine Corps' Amphibious Combat Vehicle (ACV).

The FANG program, however, is undertaking a radically novel approach to the design and manufacture of an IFV. The FANG performer will be responsible for staging a series of FANG Challenges, prize-based design competitions for progressively more complex vehicle subsystems, culminating in the design of a full IFV. The FANG Challenges will leverage the META design tools and the vehicleforge.mil collaboration environment to significantly change the design experience and open the aperture for design innovation.

The ongoing META program is on track to deliver an integrated capability for: compositional design synthesis at multiple levels of abstraction; design trade space exploration and metrics assessment with structural and information-based metrics of system complexity; formal semantic integration of models across multiple physical and cyber domains; and probabilistic verification of system correctness with respect to realistic context models using model checking and simulation traces. This capability will be embodied in several end-to-end tool chains ranging from a free, open source set of tools; to a mass-market, web-based, cloud-hosted capability; to a high-end commercial tool suite based around

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[1] See Appendix 1 for a detailed overview of the portfolio and its philosophical underpinnings.
[2] https://www.fbo.gov/spg/ODA/DARPA/CMO/DARPA-BAA-10-21/listing.html
[3] https://www.fbo.gov/spg/ODA/DARPA/CMO/DARPA-BAA-10-59/listing.html
[4] https://www.fbo.gov/spg/ODA/DARPA/CMO/DARPA-BAA-12-14/listing.html
[5] https://www.fbo.gov/spg/ODA/DARPA/CMO/DARPA-BAA-11-21/listing.html

existing computer-aided design/product lifecycle management (CAD/PLM) products.[6]

Also ongoing is the development of vehicleforge.mil, a crowd-sourcing site and capability for the collaborative development of cyber-electro-mechanical systems in a manner similar to forge sites in widespread use today for the development of software by the open source community. The principal technical challenge associated with such a capability is a general representation language that is rich enough to describe a broad range of cyber-electro-mechanical components and system designs, yet formal enough that the system can be "compiled" or verified in some manner when a design change is made to some element or aspect of it. The META tools provide just such a capability. Additionally, vehicleforge.mil is planned to incorporate a novel reputation-based credentialing scheme for users, component models, and design fragments, as well as a virtual world front end interface to provide an immersive and visually rich user experience for exploration of the design space.

Concurrent with this FANG BAA, the building of an iFAB Foundry capability to take the META IFV design representation and automatically configure a digitally-programmable manufacturing facility (termed a foundry in a nod to integrated circuit fabs and to distinguish it from a conventional factory) is solicited through the iFAB Foundry BAA.[7] Currently ongoing iFAB research activities will deliver a distributed manufacturing capability that includes the selection of participating manufacturing processes and equipment, the sequencing of the product flow and production steps, the generation of machine instruction sets, and the generation of instructions for human workers. It is anticipated that the iFAB Foundry capability is likely to result from the amalgamation of existing fabrication capabilities from a model library that characterizes the salient attributes of each modality of fabrication: cost, speed, range of applicability, speed of reconfigurability, etc. The resultant iFAB Foundry need not be manifested as a single facility co-resident under one roof; it can be a virtual aggregation of distributed capabilities, sequenced and tied together into a single resultant product flow. The FANG program will utilize this iFAB Foundry capability to produce progressively more complex vehicle subsystems, culminating in the manufacture of a full IFV.

To the extent that the META tools and the iFAB Foundry information architecture are both model-based design environments--one for vehicles, the

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[6] See Appendix 2 for a detailed overview of the META tool chain capability. A demo of one of the current META tool chains can be found at http://tinyurl.com/meta-x-1 in the form of a short screen capture video. Note that this is a snapshot of capability as it currently stands, pending an additional year-long maturation effort.

[7] https://www.fbo.gov/spg/ODA/DARPA/CMO/DARPA-BAA-12-14/listing.html

other for fabrication facilities--they are both predicated on the existence of a rich set of component models, context (environment) models, and manufacturing process models. To that end, there is an ongoing Component, Context, and Manufacturing Model Library 1 (C2M2L-1) effort,[8] which will be followed by C2M2L-2 and C2M2L-3 at appropriate intervals, designed to populate model libraries on a cadence corresponding to each FANG Challenge.

Therefore, in theory, the FANG program should culminate in the design, fabrication, and verification of the FANG IFV without the contracted FANG performer doing any of the design, fabrication, or testing. The former accomplished through crowd-sourcing; fabrication done by the iFAB network; and the need for testing obviated through formal model-based verification in the course of design (and/or re-verification of the final "as built" product). As a practical matter, it is prudent to anticipate imperfections in each of these steps, and in addition to orchestrating the FANG Challenges, the FANG performer will be required to monitor, supervise, augment, and ensure the smooth integration of each step in the end-to-end "make" process for the FANG IFV.

It is important to note, however, that this does not mean that the FANG performer must have the experience, expertise, and capital infrastructure necessary to design, build, and test a complete IFV.

In fact, in the interest of maximally opening the aperture to innovative technical and business approaches, DARPA strongly encourages the participation in this solicitation by non-traditional performers, including small businesses, research institutions, and first-time government contractors, so long as they bring a flexible and enthusiastic team and can access top-notch expertise in vehicle design, heavy manufacturing, and engineering and operational test and evaluation, along with decision theory (to support requirements development), management of social networks (to support the vehicleforge.mil community), and execution of prize challenges.

Program Overview

The FANG program is structured around three FANG Challenges. The goal of the challenges is to sequentially apply the AVM tools and processes to products of graduating level of complexity, but aligned toward the ultimate goal of building the FANG IFV. The products of the three FANG Challenges will be as follows:

[8] https://www.fbo.gov/spg/ODA/DARPA/CMO/DARPA-BAA-11-47/listing.html

1. Mobility/Drivetrain Challenge: An IFV mobility/drivetrain automotive rig for full scale dynamometer testing.
2. Chassis/Survivability Challenge: An IFV chassis/survivability suite, including a complete IFV hull structure assembly and crew compartment to be tested for static and dynamic structural properties and a demonstrated ability to incorporate modular bolt-on armor, and a complete modular armor package for both fit checking on the hull structure assembly as well as testing as survivability test articles for kinetic impact and blast.
3. Full Vehicle Challenge: A complete IFV for operational test & evaluation typical of initial lots of full rate production vehicles.

Each challenge is intended to be a stand-alone design-build-test exercise. In other words, the products of the first two challenges do not necessarily feed into the Full Vehicle Challenge. Prior practice in open source software development and crowd sourcing suggests, however, that significant design re-use will occur in the vehicleforge.mil community and should be encouraged.

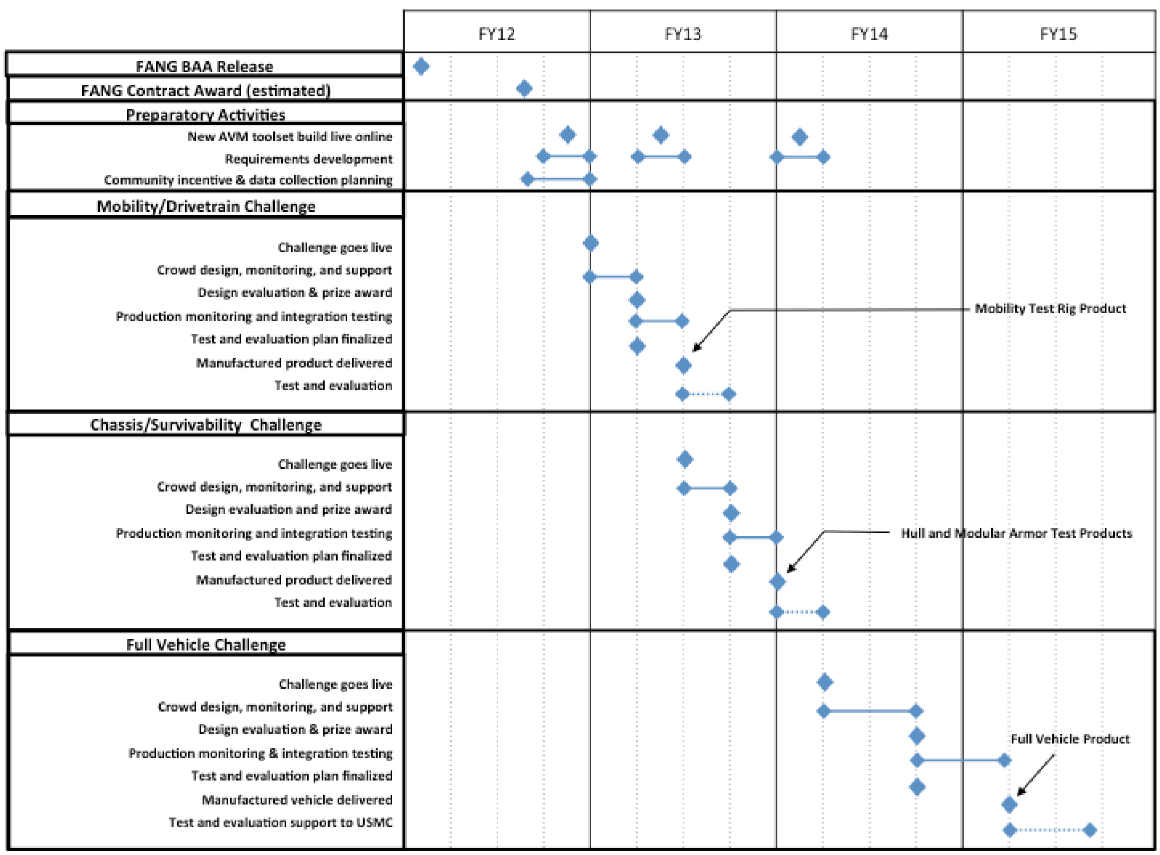

Figure 1: Notional Schedule of Principal FANG Program Activities

The total period of performance for the FANG program, during which the three FANG Challenges will be conducted, is 36 months from date of contract award.

Proposals should be structured as a 12-month base effort, followed by two sequential 12-month options. The technical effort is described for clarity as five distinct tasks. However, due to the integrated and very fast-paced nature of the technical effort, proposals should encompass all five tasks and all three FANG Challenges. The tasks are briefly as follows:

1. <u>FANG Challenge Requirements Development:</u> Represent the Marine ACV program requirements in terms of a multi-objective preference surface that enables an ordinal ranking of designs based on requirements satisfaction. This will require aggregation of input from multiple stakeholders to augment traditional requirements sources with information on relative preferences and elasticities across requirements.
2. <u>FANG Challenge Execution:</u> Develop, advertise, support, and oversee the execution of three major prize-based challenges. This will require providing support to the vehicleforge.mil community (though the site itself is separately operated), creating seed designs, and affirmative efforts to grow the community. It will also include support for the evaluation and ranking of design submissions vis-à-vis the requirements model developed in Task 1, and recommendations to DARPA for prize awardees (DARPA will make the final decision and award the monetary prizes ranging from $1 million to $2 million for each challenge).
3. <u>Oversight of FANG Builds in iFAB Foundry:</u> Assemble a complete design package (META models, bill of materials (BOM), CAD/PLM models, etc.) for the winning design to transfer to the iFAB Foundry for configuration and manufacture. Perform selective functional and integration testing (the iFAB Foundry performer is responsible for geometric metrology and quality assurance/quality control (QA/QC)) in the course of assembly and integration to identify any potential mis-matches between the "as built" product and the META models on which virtual verification of design correctness was predicated. Augmentation of gaps or deficiencies in the crowd-sourced design or selective re-design in the course of manufacturing may be required of the FANG performer.
4. <u>FANG IFV Test & Evaluation Support:</u> Develop a test and evaluation master plan (TEMP) for each FANG Challenge product, identify and retain appropriate test facilities and equipment, arrange and oversee logistics associated with test and evaluation, and support Marine Corps test activities. A single product instance is expected to be tested following FANG Challenges 1 and 2, the former principally in terms of dynamometer, terrain, and environment performance, the latter principally in terms of kinetic impact and blast testing. A single IFV will be available to the FANG performer for test and evaluation following FANG Challenge 3; however, the FANG performer should support testing of up to seven vehicles by the Marine Corps (this latter testing may be

assumed to take place at a government-furnished facility and principally entails vehicle maintenance, supply of spare parts, instrumentation, etc.).

5. AVM Software Tool Suite Support & Curation: In accord with the FANG performer's responsibility to support the vehicleforge.mil design community and FANG Challenge execution, the performer is also expected to exercise curatorial responsibilities over the META tool suites, the component and context model libraries, and the vehicleforge.mil repository of designs. Although independent performers are developing the META tools, populating the various model libraries, and operating the vehicleforge.mil infrastructure, the FANG performer will exercise cognizance over the FANG Challenge participant experience, and as such may be required to maintain version control and software distribution channels, develop tutorials, provide user support, and ensure seamless integration across the AVM tools and services infrastructure.

Detailed Description of FANG Challenges

Mobility/Drivetrain Challenge: DARPA has intentionally avoided a precise specification of the scope of the mobility and drivetrain subsystems of an IFV for fear of precluding particularly innovative designs that challenge subsystem boundaries. The general scope of this challenge encompasses: primary drive power generation (e.g., internal combustion, turbine, hybrid, electric, or other powerplant), auxiliary power generation tied to the primary drive powerplant, energy storage, transmission (likely allowing for dual-mode land and amphibious propulsion), suspension, driveline-to-ground interface (e.g., wheeled, tracked, or otherwise), secondary amphibious propulsion mechanisms (e.g., secondary driveline, clutches, waterjets), steering (both land and water), braking, and associated tribology, hydraulic, pneumatic, electrical, cooling/thermal, vetronics, and embedded/control systems (including software for control and fault management systems). Structural elements unique to the mobility subsystem are also in scope, though general elements of the vehicle frame, chassis, and protection system are instead the subject of the Chassis/Survivability Challenge. The final manufactured version of the winning design will be tested on a dynamometer rig for mobility performance, efficiency, ride quality, thermal, and other attributes that can be reasonably observed in the course of standard dynamometer testing. Consequently, for purpose of requirements development and the ability of META tools to synthesize correct-by-construction mobility/drivetrain designs, component and context models corresponding to all of these test parameters will be developed by the C2M2L-1 performers and made available to the FANG challenge participants. The prize award for the winner of this challenge will be $1 million, awarded directly by DARPA.

Chassis/Survivability Challenge: The general scope of this challenge encompasses: hull, chassis, frame/panels or monocoque structure, modular armor panels, mountings/inserts, subsystem volumetric compartment placeholders, crew compartment with crew accommodations such as seats and restraints, subsystem mounting placeholders, hull penetrations for drivetrain/grills/ hatches, hatches, and blow-out panels. The final manufactured version of the winning design will be tested using industry-standard complete coordinate dimensional metrology measurement approaches, fit checks, corrosive and environmental effects, and survivability testing for kinetic penetration and blast effects. Consequently, for purpose of requirements development and the ability of META tools to synthesize correct-by-construction chassis/survivability designs, component and context models corresponding to all of these test parameters will be developed by the C2M2L-2 performers and made available to the FANG challenge participants. The prize award for the winner of this challenge will be $1 million, awarded directly by DARPA.

Full Vehicle Challenge: The scope of the full vehicle challenge is a complete IFV design, with the exception of the command, control, communications, intelligence, surveillance, and reconnaissance (C4ISR) suite, the battle management system (BMS), and weapons. All three of these items will be specified prior to the challenge and will be supplied as government-furnished equipment (GFE) to the FANG performer for integration into the final vehicle(s) following manufacture in iFAB. It is important to note that the Full Vehicle Challenge is not predicated on the winning designs to the Mobility/Drivetrain Challenge or the Chassis/Survivability Challenge as inputs or constraints. Additional vehicle features beyond those covered in the preceding two challenges include (but are not limited to): crew accommodations, crew interfaces and vetronics, integrated vehicle management systems, fire suppression system, energy (electrical, hydraulic, pneumatic, etc.) distribution, storage, and management systems, environmental controls and ventilation. The final manufactured version of the winning design will be tested against the full range of Marine Corps ACV program requirements in a complete series of operational test and evaluation activities supported by the FANG performer. Consequently, for purpose of requirements development and the ability of META tools to synthesize correct-by-construction complete vehicle designs, a full suite of component and context models will be developed by the C2M2L-3 performers and made available to the FANG challenge participants. The prize award for the winner of this challenge will be $2 million, awarded directly by DARPA. Additionally, the winning design, upon fabrication in the iFAB Foundry and test and evaluation by the Marine Corps will be eligible for consideration as the go-forward design for the ACV program.

Task 1: FANG Challenge Requirements Development

The purpose of this task is twofold: to allocate specific subsets of Marine ACV requirements to each of the FANG Challenges and to represent ACV requirements in terms of a multi-objective preference surface that enables an ordinal ranking of alternative designs based on requirements satisfaction.

A FANG Challenge participant or team of participants--whether employing vehicleforge.mil or not--will be equipped with a set of context or environment models (developed and curated by the C2M2L performers but which will need to be managed and disseminated by the FANG performer, see Task 5) against which the META tool chain will compute the performance characteristics of their vehicle design. Thus, for instance, the META tools would use a terrain context model to compute a design's top speed, ride quality, fuel consumption, range, etc. It might use a blast context model to compute survivability properties. And a corrosion context model might provide an assessment of material degradation over time. This is the same set of context models that the FANG performer will use to help evaluate designs and recommend a winner to DARPA for the award of a prize (see Task 2). However, in order to objectively and transparently select a winning design, an analytic framework is needed by which designs can be assigned a score or at least ordered based on their satisfaction of various requirements. Ideally, the requirements multi-objective preference surface will be freely available to all FANG Challenge participants so that they can improve their vehicle against it in the course of the design challenge; this would have the added benefit of making the ranking for prize challenge award a completely transparent process.

The FANG performer will be supplied with ACV program requirements to include the Initial Capabilities Document (ICD), the Capability Development Document (CDD), and the Capability Production Document (CPD), as government-furnished information (GFI). If these documents are not available in time to meet the needs of the FANG performer, DARPA will work closely with the performer to develop a representative set of requirements based on the Expeditionary Fighting Vehicle (EFV), Amphibious Assault Vehicle (AAV), and other program documentation and reasonable assumptions.

Traditional requirements documents provide threshold and objective values for key performance parameters (KPPs), key system attributes (KSA), or other requirements. KPPs are frequently also ranked in order of importance. However, this representation neither encapsulates sufficient information nor provides a framework by which alternative designs can be ordered or ranked based on the degree to which they satisfy various requirements. In the course of this task, the FANG performer is expected to develop a representation framework that enables the construction of a multi-objective preference surface that captures both a continuous preference profile with respect to any single requirement, as well as the relative preference or preference elasticity across different requirements. To provide a simplistic example, in a world where vehicles have only three requirements: mobility (top speed in km/hr), range (km), blast survivability (kg of explosives), we would like to be able to provide a definitive ordinal ranking of designs D_1 = {70 km/hr, 500 km, 15 kg}, D_2 = {60 km/hr, 400 km, 5 kg}, and D_3 = {80 km/hr, 600 km, 10 kg}. It is immediately apparent that both designs D_1 and D_3 are Pareto-superior (dominant along all three axes) to design D_2. But the ability to rank between designs D_1 and D_3 depends both on the individual importance of mobility, range, and survivability, as well as the relative elasticity between the three attributes.

Decision theory is a well-established field at the intersection of economics, psychology, and operations research that provides several frameworks for delivering this capability, including multi-attribute value functions and multi-attribute utility functions.[9] Proposers are encouraged to propose other approaches,[10] but should compare them and justify their choice against these two mainstream methodologies. In addition to providing a framework for ordering designs, proposers should propose an approach to remedying the information gap between what is available in traditional requirements documents and what is necessary to support their decision framework. Another sample approach to constructing multi-attribute utility functions is through stakeholder interviews involving lottery equivalence questions. These can be cumbersome and time-consuming, but reveal a stakeholder's risk aversion profile vis-à-vis each attribute or requirements, and are likely less prone to gaming and strategic behavior on the part of the interviewees. FANG proposers should provide a detailed plan for extracting the necessary information to augment ACV requirements documents and support their proposed requirements framework.

Should the FANG performer desire to conduct stakeholder interviews, the government will facilitate access to appropriate stakeholders; these should be identified with specificity in the proposal. Proposers should also discuss their approach to stakeholder selection (should they be users? maintainers?

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[9] The definitive treatise on the subject is R.L. Keeney & H. Raiffa, *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*, Cambridge University Press, Cambridge, UK, 1993.

[10] The field of mechanism design has seen some interesting approaches that can be used for preference revelation, for instance the Groves-Ledyard Mechanism. See T. Groves & J. Ledyard, "Optimal Allocation of Public Goods: A Solution to the 'Free Rider' Problem," *Econometrica*, Vol. 45, No. 4, May 1977, pp. 783-809; T. Groves, "Efficient Collective Choice when Compensation is Possible," *The Review of Economic Studies*, Vol. 46, No. 2, April 1979, pp. 227-241. The pioneering work on mechanism design generally is L. Hurwicz, "The design of mechanisms for resource allocation," *American Economic Review*, Vol. 63, 1973, pp. 1-30. Another popular approach for preference revelation is called contingent valuation. See R.C. Mitchell & R.T. Carson, *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Resources for the Future, 1989.

acquisition officials? senior leaders?) and aggregation of preferences across multiple stakeholders. The latter is a notoriously challenging problem. Proposers should address the scalability of their proposed approach to large requirements sets (many hundreds of requirements) as one would expect of a major vehicle acquisition program. Finally, proposers should detail a plan to verify the results of their analytic framework for consistency with ACV requirements.

The deliverables of this task include several initial planning reports and a set of requirements models associated with each of the three challenges. These are detailed in Table 1 below.

Task 2: FANG Challenge Execution

This task represents perhaps the most crucial of all FANG activities: the orchestration and conduct of FANG Challenges. The FANG performer will be responsible for all aspects for challenge execution and will act as an integrator of capabilities delivered by the vehicleforge.mil, META, and iFAB Foundry performers. Additionally, the FANG performer will be required to work exceptionally closely with the DARPA program management team and Public Affairs Office due to the high-visibility nature of the challenges. What follows is a non-exhaustive, loosely chronological list of major activities notionally envisioned as part of challenge execution. Proposers are expected to possess significant independent expertise in conducting challenge-type activities and are free to augment or recast this list in the proposal based on their own experience.

FANG proposers may assume that:

- The responsibility for operation of vehicleforge.mil as an infrastructure service lies with the vehicleforge.mil performer.
- vehicleforge.mil will provide flexible access control and click-through licensing features to support open (public) and closed (private) collaborative work spaces with easily configurable licensing terms and policies for each work space.
- Component and context model libraries are populated and curated by C2M2L performers.
- One or more complete META tool suites are available freely to the FANG Challenge participant community.
- The iFAB Foundry performer provides a service by which the manufacturability of a given design can be queried and assessed; or that such a capability is directly present in the META tools.

Working closely with DARPA, the FANG performer will be expected to develop rules for participation in the FANG challenges, including qualifying and disqualifying factors for participants, permissible and impermissible behaviors, and appropriate remedial actions for participant malfeasance.

The FANG performer is expected to seed the vehicleforge.mil environment with sample designs, ranging from assemblies to subsystems to complete systems aspects of which can serve as points of departure for FANG IFV designs. Relevant seed designs can be for other military vehicles, commercial vehicles, or other relevant cyber-electro-mechanical systems. The FANG performer will be expected to secure appropriate rights to such designs, although DARPA will take a strong supporting role in this effort, particularly vis-à-vis designs to which the government already possesses significant rights.

The FANG performer will have principal responsibility for seeding, nurturing, and growing the FANG designer community using the vehicleforge.mil collaboration tools. The FANG performer will have input to the vehicleforge.mil performer on specific community features. Presently envisioned are message boards, wikis, mailing lists, and a live chat capability. Likely participants in FANG Challenges fall into a spectrum ranging from individuals who will contribute to open designs, to small businesses who may utilize closed work spaces for design collaboration, to traditional IFV contractors.

The FANG performer will be required to support DARPA's messaging and public outreach strategy to engage participants in FANG Challenges. Key publics for this outreach strategy include individual university students, university student clubs, do-it-yourself (DIY) communities, automotive enthusiasts, members of the armed forces, hackerspaces, open source software enthusiasts, small businesses, specialist engineers including at traditional and non-traditional contractors, and traditional and non-traditional contractors. International outreach may be required. The FANG performer will be expected to coordinate closely with the DARPA public affairs team to ensure that all public outreach is vetted, approved, and consistent with DARPA's messaging strategy for the FANG program and AVM portfolio.

The FANG performer will be responsible for ensuring that FANG requirements models, C2M2L models, META software, and all documentation is assembled from the respective performers, is up to date, packaged for easy distribution and appropriately explained. The FANG performer may be required to develop tutorials or promotional materials explaining various aspects of the tools and models needed to participate in FANG Challenges.

Upon commencement of each FANG Challenge, the FANG performer will be required to monitor progress of the designer community in near real time, collect statistics, and provide updates to DARPA on a daily basis. The FANG performer will be required to liaise with the vehicleforge.mil performer to assemble and parse statistics on resource usage and design progress, and provide recommendations to DARPA on any course corrections that may be needed to ensure successful execution of the challenge.

The FANG performer should be prepared to support a fallback approach to credentialing of vehicleforge.mil users through manual verification of U.S. person status and coordinating with the vehicleforge.mil performer to set access permissions accordingly. This may involve collection of faxed or mailed documentation from potential users.

The FANG performer will need to ensure that appropriate access control and intellectual property policies are enforced for each design or vehicleforge.mil work space. As previously noted, the vehicleforge.mil performer is responsible for creating and certifying information assurance features and controls to enable this enforcement. The FANG performer, however, will need to exercise oversight, perform spot checks, and ensure that appropriate policies accompany the design even when it is outside the custody of the vehicleforge.mil environment (e.g., in transmission to the iFAB Foundry, in evaluation, etc.)

The FANG performer should plan to provide support to the vehicleforge.mil design community throughout the challenges through active and rapidly responsive participation in discussions forums, message boards, wikis, responses to e-mail questions, and daily live chat sessions. If a virtual world front-end to vehicleforge.mil becomes operational as anticipated, the FANG performer is expected to maintain an active and helpful presence in the virtual world environment to assist challenge participants.

Upon completion of each design challenge, the FANG performer is expected to screen submitted designs for completeness and any abnormalities. Following the completion of screening, the FANG performer will provide to DARPA a ranking of the designs with respect to the requirements model developed in Task 1. Upon verification, if DARPA concurs with the result, a prize award will be issued to the winning design team according to the terms stipulated in the license associated with that design/work space. Prize awards will be issued directly by DARPA.

Upon the selection of a winning design, the FANG performer will be responsible for performing detailed multi-physics model-based verification (e.g., using full non-linear partial differential equation solvers) using META and other industry-standard state-of-the-art computational modeling tools. Additionally, the FANG performer should anticipate some amount of “gap filling” in the winning design due to partial incompleteness of submissions, model inaccuracies, inconsistencies, and possible deficiencies in the design tools, environment, or collaboration infrastructure. Consequently, the FANG performer should have at least a modest capability to complete or re-work an IFV design.

Finally, the FANG performer will be responsible for assembling a full META model, CAD geometry, and bill of materials (BOM) for the winning design, working with the iFAB Foundry performer to do a final manufacturability check, and transmit the design to the iFAB Foundry for manufacture.

The deliverables of this task include a planning report corresponding to each challenge, daily status reporting on challenge progress while the design period is ongoing, a ranked list of challenge entries, a complete backup of all vehicleforge.mil contents at the conclusion of each design challenge, and the complete technical data package for the winning design of each challenge. These are detailed in Table 1.

Task 3: Oversight of FANG Builds in iFAB Foundry

In theory, a design that is verified against an appropriate range of context models by the META tools is correct by construction. In other words, if it is manufactured to precisely reflect the META model of the design, it will function as simulated. As a practical matter, since this is a research effort, the first few times that the AVM construct is exercised, it is prudent to expect occasional errors in the component models from which the design is constructed, for context models to be imperfect representations of the environment particularly when highly nonlinear phenomena are involved, and for a design that might have been assembled by a community of thousands or tens of thousands of individual members to have other imperfections. The FANG performer will assume total stewardship of the winning FANG Challenge designs from the time the winning design is identified (described in Task 2), through the build cycle in the iFAB Foundry, and through test and evaluation (described in Task 4).

Though a separate iFAB Foundry performer will be responsible for the development and operation of the digitally-programmable manufacturing network that is iFAB, that performer is not expected to have any depth of understanding of the design itself nor domain expertise in vehicles; they are running what is in essence a build-to-print manufacturing operation. Part of the responsibility of the iFAB performer will be to collect metrology and conduct quality assurance/quality control (QA/QC) as the FANG Challenge products are being manufactured. However, this mostly constitutes geometric verification and identification of manufacturing defects. The iFAB performer is neither equipped nor required to conduct developmental or integration testing of the product as it is being fabricated and assembled.

To perform such developmental/integration testing, proposers should plan to situate a portion of their performer team at the iFAB Foundry final assembly node to perform periodic functional testing at various levels in the system in the course of manufacture. The iFAB Foundry final assembly node will be situated at Rock Island Arsenal; the facility is described in more detail in Appendix 4. In order to assist proposers with scoping their effort under this task, the following general guidelines for developmental/integration testing are offered. These are not intended to be prescriptive, and proposers are welcome to deviate from them based on their own experience, so long as the rationale for any such departures is clearly articulated in the proposal. References to work breakdown structure (WBS) levels correspond generally to the notional IFV WBS/BOM supplied in Appendix 5.

- Verification of custom-manufactured component specifications and tolerances at the lowest numbered part level (typically WBS level 6 or 7) at a 10% sampling rate (1 in 10 components) and for off-the-shelf (OTS) components at a 1% sampling rate (1 in 100 components).
- Verification and validation of assembly- and subsystem-level power-on performance at WBS levels 2 and 3, for example: engine system, transmission system, suspension wheel stations and assemblies, fuel system, air intake system, etc.
    - A dynamometer capability to confirm powertrain performance, consisting of engine, transmission, cooling, fuel delivery, lubrication, intake/exhaust, electrical, hydraulic, and controls in ambient and hot/cold conditions
    - A suspension test capability that allows dynamic testing of all unique wheel stations at simulated terrain conditions
    - A vetronics system integration test bed, sometimes referred to as a Systems Integration Lab (SIL) setup to benchtop test all electronic, power, energy, supply, distribution, and control components
    - A dimensional metrology capability to measure hull structure to stated design tolerances at the scale of an IFV product of this class
    - Assembly checks of key systems, e.g., pressure checks of air, coolant, hydraulic lines and systems, preliminary check of fire suppression systems, etc.
- Validation of high-level acceptance parameters for the complete FANG Challenge products as a roll-out article before commencement of operational test and evaluation (Task 4). Proposers should outline a preliminary plan with acceptance criteria with an indication of required test procedures, equipment, or services. These are intended to be basic system function checks and not detailed test and evaluation

Proposers need to clearly identify and include in their proposals methods and equipment required for each category of testing either by procuring the requisite equipment or through service agreements with outside vendors. Proposers should not assume any government-furnished equipment or capabilities except as identified in the description of the Rock Island Arsenal facility in Appendix 4. Any equipment that is purchased with FANG funds must be placed at the Rock Island facility.

Where discrepancies occur, it is the FANG performer's responsibility to develop an engineering fix, update the design technical data package, perform any virtual re-verification of the design using META and other tools, and to supply the corrected design and any re-work instructions to the iFAB Foundry performer. The cost associated with delays and re-manufacture will not be borne by the FANG performer, however proposers should plan for the occurrence of such occasional remedial re-design cycles with the first few AVM products.

A single build of the Mobility/Drivetrain winning design is anticipated. Likewise, a single build of the Chassis/Survivability winning design is expected. Up to eight vehicles are expected to be produced based on the winning Full Vehicle Challenge design.

Deliverables from this task include developmental/integration test reports for all three FANG Challenge products. Additionally, updated design technical data packages (META models, CAD models, BOMs) to correct issues or design flaws discovered during developmental/integration testing shall be delivered. The performer should also correct any component or context model mismatches discovered in the course of performing this task.

Task 4: FANG IFV Test & Evaluation Support

As FANG challenge products are completed and delivered from the iFAB Foundry facility, an exhaustive set of functional testing and evaluation will be undertaken to verify the extent to which META predictions of design correctness vis-à-vis various requirements are borne out. The FANG performer will, in large measure, be responsible for the development of test plans in consultation with DARPA and the Marine Corps, as well as the execution of the testing with the exception of operational test and evaluation of the complete IFV emanating from the Full Vehicle Challenge which will be undertaken by the Marine Corps with in-field sustainment and support from the FANG performer. DARPA, in coordination with test entities such as the Marine Corps Operational Test and Evaluation Activity (MCOTEA) and the Army Test and Evaluation Command (ATEC), will provide high-level input and objectives for the development of test plans by the FANG performer, and particularly for the development of the Test and Evaluation Master Plan (TEMP) for the complete FANG IFV.

Following the Mobility/Drivetrain Challenge, the FANG performer will be responsible for executing testing of one vehicle test rig within a large scale vehicular dynamometer able to handle the system in total and expose it to representative driving conditions (flat & slope, pavement & cross country terrain, dry & wet conditions, etc.) that exercise the powertrain, plus varying terrain contours with typical of IFV testing environment and RMS terrain roughness levels to exercise the suspension. A mix of ambient conditions representative of environments stated in requirements (expected to be on the order of ranging from 32 degrees F to 120 degrees F) will be tested concurrently. Proposers should make an economic decision between including the procurement of appropriate test equipment as part of their proposed FANG effort, or the utilization of outside services to provide such capability, in which case logistics and transport costs should be incorporated into the proposal. Equipment that is procured with FANG funds must be located at the designated Rock Island Arsenal facility. Expectations are that such testing is on the order of 2-3 months to accommodate the entire performance envelope of the Mobility/Drivetrain product as well as provide endurance testing.

For Chassis/Survivability Challenge product, testing of the single manufactured article will be bifurcated. For the hull article, the proposer should plan to perform a detailed dimensional metrology analysis of the hull to design specifications. The FANG performer will be responsible for all dimensional criteria (drawn from design specifications in the META design) and the process, equipment, and location at which metrology is performed. Proposers should make an economic decision between including the procurement of appropriate test equipment as part of their proposed FANG effort, or the utilization of outside services to provide such capability, in which case logistics and transport costs should be incorporated into the proposal. For the modular armor article, the FANG performer will likewise provide dimensional metrology analysis of the armor panels and their fit checks/assembly to the hull article. Secondly, the proposer will execute a live fire test protocol to assess the survivability features of the vehicle structure and modular armor panels. Testing will include the full range of effects, including various kinetic rounds and blast effects. DARPA and the Marine Corps may provide limited support and a government facility, though proposers should plan for the eventuality of conducting such testing without reliance on government facilities yet those that meet credibility standards of the Marine Corps, and can be observed directly by Marine Corps and DARPA stakeholders.

For the Total Platform Challenge product, the proposer will support a DARPA and service test element partner with the development of a thorough vehicle and system test and evaluation master plan (TEMP) of the magnitude corresponding to a limited production IFV product. The plan will include performance testing of one to eight vehicles for approximately 3 months (for proposal planning purposes, assume at Aberdeen Proving Grounds, MD) and endurance testing for approximately 2 months (for proposal planning purposes, assume Camp Pendleton, CA).

For all testing and evaluation, the proposer should present plans for complete support of FANG Challenge product storage, maintenance, and operational support. In other words, once production is complete, the FANG performer will be responsible for operation, housing, delivery, and care/maintenance of FANG Challenge products as they are employed in test and evaluation activities. As such, the proposer should provide estimates of logistical personnel, safety personnel, drivers/operators, transportation to/from test locations, care and maintenance of product during testing, appropriate spares, storage, etc. For proposal planning purposes, proposers should assume that manufactured articles are delivered by the iFAB Foundry performer to the FANG performer at Rock Island Arsenal, IL.

Should the proposer choose to procure dynamometer, metrology, or other heavy equipment for this task, the proposer should plan to situate such equipment at Rock Island Arsenal. A description of the available facility space may be found in Appendix 4.

Deliverables of this task include test plans and test reports for products resulting from each of the three FANG Challenges.

Task 5: AVM Software Tool Suite Support & Curation

As one of the principal responsibilities of the FANG performer is the integration of various generic AVM infrastructure efforts toward a concrete product application, the FANG performer must necessarily play a curatorial and support role to ensure that the various tools under development by META, iFAB, vehicleforge.mil, and C2M2L performers (and the FANG performer itself, e.g., in Task 1) are properly tested, maintained, documented, supported, and distributed.

The META program has converged toward at most three separate end-to-end tool suites that enable a designer to go from requirements and design trade space exploration, through a series of steps wherein the size of trade space and state space is reduced while the model order (model fidelity) is increased, toward a complete co-verification of the design across multiple physical and cyber domains. Such verification is necessarily probabilistic due to the fact that component models from which the design is composed have inherent uncertainties associated with their data content. META tools output a complete model-based representation of the design, and are also capable of synthesizing standard BOMs, CAD models, and PLM data associated with the design. The META tool chains range from a completely free, open source research core best suited to sophisticated users who do not expect a polished and seamless interface, to mass-market tool chain that is principally web-based and cloud-hosted and geared toward an average educated individual, to a high-end tool chain that is based on an existing high-end CAD/PLM system and is geared toward industry users.

The iFAB tool suite takes the output META model representation of a design and configures an iFAB capability to manufacture that design. The iFAB tools map a model-based characterization of a wide arrange of manufacturing processes--machines, humans, assembly operations--into a set of potential foundry configurations capable of manufacturing the vehicle design received from META. The space of possible configurations can be assessed against various metrics such as transit speed, production rate, labor intensity, unit cost, foundry cost, etc. Once a particular foundry configuration is selected, the iFAB tools generate computer numerically controlled (CNC) instructions, human instruction sets, and training modules to rapidly instantiate the chosen configuration. At its core, iFAB is an information architecture that ties together a distributed network of manufacturing equipment with a common set of modeling and data representation standards. The approach to feeding iFAB manufacturability constraints back to META vehicle design tools has yet to be fully fleshed out and finalized. This may be a fully autonomous capability integrated into the META tools (i.e., the tools would be able to parse the iFAB/C2M2L manufacturing model library and directly infer constraints on the vehicle design trade space), or it may be a service provided by the iFAB Foundry performer whereby a design is submitted and manufacturability feedback is provided with minimal latency. Some combination of the two approaches is likely.

A more detailed description of the META and iFAB tools can be found in Appendix 2 and in their respective solicitations cited in introductory section of this BAA.

vehicleforge.mil can be thought of as a front-end collaboration environment for users of META tools. It serves as a model and design repository, enabling features like check-out/check-in of portions of a design, version control, branching, etc. It also provides collaboration features like message boards, wikis, and live chat. vehicleforge.mil supports both open and closed work spaces or design trees, with the owner of a new work space or the root node of a design tree empowered to set the access control, licensing, and intellectual property policies for that work space. Participating users must agree to the policies in order to gain access. These policies can include rules for sharing potential prize winnings, accrual of royalties, or be very simple--corresponding to liberal open source licensing of the design. vehicleforge.mil will also have a reputation-based credentialing scheme for users, models, and designs, as well as an experimental virtual world front-end to enable an immersive experience for design visualization, manipulation, and collaboration. The source code to vehicleforge.mil itself is entirely open source and will be maintained for the duration of the AVM effort by a dedicated vehicleforge.mil contractor.

C2M2L performers share a role for model library curation with vehicleforge.mil. While vehicleforge.mil will provide hosting services, C2M2L performers are responsible for ensuring semantic consistency across models, mapping domain-specific model representations into a common semantic domain, and tracking model provenance.

Finally, as described in Task 1, the FANG performer may also have some limited responsibility for the development of models (and perhaps supporting tools, if warranted) for requirements representation and design ranking.

While the development of most of the aforementioned capabilities lies with the respective performer organizations, it will be the FANG performer's responsibility to provide:

- Evaluation and deployment testing of the tools with representative cross sections of the target user community.
- Maintenance of the various tools to ensure consistency of interfaces across tools and performers, coordination of versioning and upgrades, prioritization of bug fixes.
- Ensure that documentation supplied by the respective tool developers is sufficient, and potentially augment it when it is deficient. In particular, this may involve the development of tutorials, frequently asked questions (FAQ) documents, demonstration videos, etc. that are targeted to the specific FANG Challenge target user bases.
- Provide technical support for the tools both during FANG Challenges (as described in Task 2), and at a slower pace outside of FANG Challenges, to ensure that bugs, flaws, and requests for new features are reported and tracked.
- Ensure that all tools are available for distribution both via vehicleforge.mil, software forge sites, and directly from the FANG performer to ensure their widespread availability with clear versioning and packaging.

Deliverables from this task include: a detailed tools curation plan shortly after FANG contract award once the FANG performer gains detailed familiarity with all AVM tools performers; consistent online availability of all tools; and the packaging of latest versions of all available AVM tools, documentation, tutorial materials, etc. prior to each FANG Challenge.

II. STRUCTURE OF AWARD

Award Instrument

DARPA anticipates making a single award under this BAA. The award will be either a procurement contract or, where deemed necessary and where appropriate statutory conditions are met, an other transaction agreement (OTA).[11] The procurement contract may either be a cost plus fixed fee (CPFF) instrument (or cost plus zero fee in cases where the performer is a non-profit entity) where the awardee has a Defense Contract Audit Agency (DCAA)-approved cost accounting system or a firm fixed price (FFP) instrument in cases where the awardee does not have an approved accounting system, has a preference for an FFP contract, or where the Contracting Officer deems it appropriate. In cases where an FFP contract is utilized, payments will be conditioned on periodic deliverables such as monthly reports so as not to increase the performance risk borne by the awardee vis-à-vis a CPFF instrument.

The award will be structured as a 12-month base period, with two sequential 12-month options, for a total 36-month period of performance. Proposers should structure their proposals accordingly, and both options must be fully priced in the proposal.

Contract Deliverables & Reviews

Proposers should propose an appropriate schedule of deliverables and milestones in their statement of work (SOW) with dates indicated as relative values after contract award (ACA). That schedule should be congruent or constitute a superset of the minimal deliverables outlined in Table 1 below. Written deliverables should generally take the form of written reports in Adobe PDF format. Where appropriate, enclosures should include complete diagrams, schematics, data sets, models, algorithms, source code, object code, executable code, documentation, test/use cases, and hardware implementing the capability described in this BAA. Where feasible, a flat-file representation of the enclosed

[11] Offerors interested in receiving an OTA are asked to submit proposal responses that accommodate both options. The government will evaluate all offerors' procurement contract proposals in accordance with the established evaluation criteria. After award selection based on these proposals, the government will evaluate the selected awardees OTA proposal with the intent of selecting the program approach offering the most benefit to the government. The intent behind this evaluation approach is to prevent offerors with greater financial flexibility and resources from reducing the proposed cost to the government by providing a large cost share or extra effort beyond that of a contractor with less financial capability.
For further information on OTAs, see:
http://www.darpa.mil/Opportunities/Contract_Management/Other_Transactions_and_Technology_Investment_Agreements.aspx.

item should be included as an appendix to the PDF report. Draft versions of all deliverables (except hardware) should be supplied 30 calendar days prior to the deliverable due date.

Table 1: Technical Deliverables

Task	Deliverable (format; timing)
Task 1 – FANG Challenge Requirements Development	• Detailed requirements approach and stakeholder interview plan (report; 2 mo. ACA) • Synthesis and allocation of ACV requirements (report, 2 mo. ACA) • Mobility/Drivetrain Challenge requirements model (models, data, report; 4 mo. ACA) • Chassis/Survivability Challenge requirements model (models, data, report; 10 mo. ACA) • Full Vehicle Challenge requirements model (models, data, report; 16 mo. ACA)
Task 2 – FANG Challenge Execution	• Mobility/Drivetrain Challenge execution plan (report; 3 mo. ACA) • Challenge execution status report (report; daily during mo. 4-7 ACA) • Ranked list of challenge entries (report; 7 mo. ACA) • Tech data package for winning design (models, data, software; 8 mo. ACA) • vehicleforge.mil contents backup (models, data, software; 9 mo. ACA) • Chassis/Survivability Challenge execution plan (report; 9 mo. ACA) • Challenge execution status report (report; daily during mo. 10-13 ACA) • Ranked list of challenge entries (report; 13 mo. ACA) • Tech data package for winning design (models, data, software; 14 mo. ACA) • vehicleforge.mil contents backup (models, data, software; 15 mo. ACA) • Full Vehicle Challenge execution plan (report; 17 mo. ACA) • Challenge execution status report (report; daily during mo. 18-24 ACA) • Ranked list of challenge entries (report; 24 mo. ACA) • Tech data package for winning design (models, data, software; 25 mo. ACA) • vehicleforge.mil contents backup (models, data, software; 26 mo. ACA)
Task 3 – Oversight of FANG Builds in iFAB Foundry	• Developmental/integration test report and revised tech data package for Mobility/Drivetrain product (report, models, software; 10 mo. ACA)

	• Developmental/integration test report and revised tech data package for Chassis/Survivability product (report, models, software; 16 mo. ACA) • Developmental/integration test report and revised tech data package for Full Vehicle product (report, models, software; 31 mo. ACA)
Task 4 – FANG IFV Test & Evaluation Support	• Test and evaluation plan for Mobility/Drivetrain product (report; 7 mo. ACA) • Test and evaluation plan for Chassis/Survivability product (report; 13 mo. ACA) • Test and evaluation master plan (TEMP) for Full Vehicle product (report; 28 mo. ACA) • Test report for Drivetrain/Mobility product testing (report; 16 mo. ACA) • Test report for Chassis/Survivability product testing (report; 22 mo. ACA) • Test report for Full Vehicle testing (report; 36 mo. ACA)
Task 5 – AVM Software Tool Suite Support & Curation	• Curation plan (3 months after contract award) • Mobility/Drivetrain Challenge tools and documentation (software, documentation; 4 mo. ACA) • Chassis/Survivability Challenge tools and documentation (software, documentation; 10 mo. ACA) • Full Vehicle Challenge tools and documentation (software, documentation; 16 mo. ACA)
Final Reports	• Base period final technical and programmatic report and delivery of all program data, software, and items/articles (report, models, data, software, documentation, hardware; 12 mo. ACA) • Option 1 period final technical and programmatic report and delivery of all program data, software, and items/articles (report, models, data, software, documentation, hardware; 24 mo. ACA) • Option 2 period final technical and programmatic report and delivery of all program data, software, and items/articles (report, models, data, software, documentation, hardware; 36 mo. ACA) • Technical manuscript summarizing key technical accomplishments suitable for publication in a peer-reviewed journal (report; 12 mo. ACA) • Technical manuscript summarizing key technical accomplishments suitable for

	publication in a peer-reviewed journal (report; 24 mo. ACA) • Technical manuscript summarizing key technical accomplishments suitable for publication in a peer-reviewed journal (report; 36 mo. ACA)

Additionally, certain periodic deliverables will be expected of the performer. These are summarized in Table 2 below. All deliverables except Monthly Financial & Hours Reports and where the protection of third-party proprietary or Privacy Act information requires otherwise, will be shared throughout the AVM performer community and will ultimately be publicly released where policy considerations and export controls allow. The Monthly Financial & Hours Reports must include the number of hours worked by contractually-identified key personnel in the preceding month. The key personnel hour amounts of these reports need not be auditable figures and may be informally gathered by the performer's project manager. No draft versions of monthly or weekly deliverables are required; however, draft versions of the PI meeting presentations will be required one week in advance of the PI meeting.

Table 2: Periodic Deliverables

Periodic Reporting Items	Means of Delivery
Bi-Monthly Presentations and Demos at AVM PI Meetings	PI meetings at major U.S. metropolitan areas (open to all AVM PIs)
Monthly Technical Report	Sharepoint (open to all AVM PIs) and e-mail
Monthly Financial & Hours Report	Sharepoint (open to government only) and e-mail
Weekly Informal Progress Updates	Video or teleconference (30-45 mins avg duration)
Reports per Milestone/Deliverable	Sharepoint (access on case-by-case basis)
Hardware Items per Milestone/Deliverables	Rock Island Arsenal, IL or another government-designated site in continental United States

Any equipment or other hardware items procured or developed with FANG program funds will become the property of the government and shall be left in place or delivered to Rock Island Arsenal, IL at the conclusion of the contracted effort.

Intellectual Property & Data Handling

DARPA desires Unlimited Rights, as defined in DFARS 252.227-7013, -7014,[12] to all deliverables generated by the FANG performer under this effort except clearly-identified, widely-available, commercial software tools, with their commercial availability described and substantiated in the proposal.

[12] http://www.acq.osd.mil/dpap/dars/dfars/html/current/252227.htm#252.227-7013

Additionally, the FANG performer should take affirmative steps for open source promulgation of all software, models, and documentation delivered under this effort. To this end, all software, models, and documentation should be licensed in accordance with the terms of Appendix 3 and incorporate the license text.

The above stipulations do not apply to third-party technical data or software that is handled by the FANG performer, e.g., as with third-party designs submitted in response to FANG Challenges. The FANG performer shall comply with the licensing requirements as set by the owner of the design, except that in all cases the FANG performer shall ensure that each such license provides at least Government Purpose Rights (GPR), as defined in DFARS 252.227-7013 and -7014 (GPR may be provided without reversion to Unlimited Rights after five years).

The FANG performer must exercise appropriate measures and controls to protect such third-party proprietary information from inadvertent disclosure while in the performer's custody. Note that vehicleforge.mil performers have independent requirements for appropriate information assurance controls; proposers to this BAA can assume adequate implementation of these controls.

Although the status of individual component models vis-à-vis the International Traffic in Arms Regulations (ITAR) is currently under review by the government, it is likely that at least some IFV designs will fall within the scope of 22 CFR § 121, The United States Munitions List.[13] The following clause will be included in all procurement contracts, and may be included in Other Transactions as deemed appropriate:

(a) Definition. "Export-controlled items," as used in this clause, means items subject to the Export Administration Regulations (EAR) (15 CFR Parts 730-774) or the International Traffic in Arms Regulations (ITAR) (22 CFR Parts 120-130). The term includes:

1) "Defense items," defined in the Arms Export Control Act, 22 U.S.C. 2778(j)(4)(A), as defense articles, defense services, and related technical data, and further defined in the ITAR, 22 CFR Part 120.

2) "Items," defined in the EAR as "commodities", "software", and "technology," terms that are also defined in the EAR, 15 CFR 772.1.

(b) The Contractor shall comply with all applicable laws and regulations regarding export-controlled items, including, but not limited to, the requirement for contractors to register with the Department of State in accordance with the

[13] http://www.pmddtc.state.gov/regulations_laws/documents/official_itar/ITAR_Part_121.pdf

ITAR. The Contractor shall consult with the Department of State regarding any questions relating to compliance with the ITAR and shall consult with the Department of Commerce regarding any questions relating to compliance with the EAR.

(c) The Contractor's responsibility to comply with all applicable laws and regulations regarding export-controlled items exists independent of, and is not established or limited by, the information provided by this clause.

(d) Nothing in the terms of this contract adds, changes, supersedes, or waives any of the requirements of applicable Federal laws, Executive orders, and regulations, including but not limited to—

(1) The Export Administration Act of 1979, as amended (50 U.S.C. App. 2401, et seq.);

(2) The Arms Export Control Act (22 U.S.C. 2751, et seq.);

(3) The International Emergency Economic Powers Act (50 U.S.C. 1701, et seq.);

(4) The Export Administration Regulations (15 CFR Parts 730-774);

(5) The International Traffic in Arms Regulations (22 CFR Parts 120-130); and (6) Executive Order 13222, as extended;

(e) The Contractor shall include the substance of this clause, including this paragraph (e), in all subcontracts.

Publication Approval

As of the date of publication of this BAA, DARPA expects that program goals for this BAA may be met by proposers intending to perform 'fundamental research,' i.e., basic or applied research performed on campus in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization the results of which ordinarily are restricted for proprietary or national security reasons. Notwithstanding this statement of expectation, DARPA is not prohibited from considering and selecting research proposals that, while perhaps not qualifying as 'fundamental research' under the foregoing definition, still meet the BAA criteria for submissions. If proposals are selected for award that offer other than a fundamental research solution, then DARPA will either work with the proposer to modify the proposed statement of work to bring the research back into line with fundamental research or else the proposer will agree to restrictions in order to receive an award. See paragraphs below for further information on fundamental, non-fundamental and restricted research. In all cases, the DARPA contracting officer shall have sole discretion to select award instrument type and to negotiate all instrument provisions with selectees.

It is the policy of the Department of Defense that the publication of products of fundamental research will remain unrestricted to the maximum extent possible. The definition of Contracted Fundamental Research is:

> "Contracted Fundamental Research includes [research performed under] grants and contracts that are (a) funded by budget category 6.1 (Basic Research), whether performed by universities or industry or (b) funded by budget category 6.2 (Applied Research) and performed on-campus at a university. The research shall not be considered fundamental in those rare and exceptional circumstances where the applied research effort presents a high likelihood of disclosing performance characteristics of military systems or manufacturing technologies that are unique and critical to defense, and where agreement on restrictions have been recorded in the contract or grant." Such research is referred to by DARPA as "Restricted Research."

Pursuant to DoD policy, research performed under contracts that are (a) funded by budget category 6.2 (Applied Research) and NOT performed on-campus at a university or (b) funded by budget category 6.3 (Advanced Research) does not meet the definition of fundamental research. Publication restrictions will be placed on all such research.

It is anticipated that awards for both Fundamental and Non-fundamental Research may be made as a result of this BAA. Appropriate clauses will be included in resultant awards for Non-fundamental Research to prescribe publication requirements and other restrictions, as appropriate. DARPA does not anticipate applying publication restrictions of any kind to Fundamental Research to each individual award that may result from this BAA. All Non-fundamental Research performers will be subject to pre-release review by the DARPA Public Release Center of any documents, reports, publications, press releases, web postings, blogs, tweets, and any other public release of information generated under or pertaining to the program. Note that briefings and demos at AVM PI meetings do not constitute public release of information as they are not open fora.

For certain research projects, it may be possible that although the research being performed by the Prime Contractor is Restricted Research, a subcontractor may be conducting Contracted Fundamental Research. In those cases, it is the Prime

Contractor's responsibility to explain in their proposal why its subcontractor's effort is Contracted Fundamental Research.

The following same or similar provision will be incorporated into any resultant Restricted Research or Non-Fundamental Research procurement contract or other transaction:

> There shall be no dissemination or publication, except within and between the Contractor and any subcontractors, of information developed under this contract or contained in the reports to be furnished pursuant to this contract without prior written approval of DARPA's Public Release Center (DARPA/PRC). All technical reports will be given proper review by appropriate authority to determine which Distribution Statement is to be applied prior to the initial distribution of these reports by the Contractor. With regard to subcontractor proposals for Contracted Fundamental Research, papers resulting from unclassified contracted fundamental research are exempt from prepublication controls and this review requirement, pursuant to DoD Instruction 5230.27 dated October 6, 1987.
>
> When submitting material for written approval for open publication, the Contractor/Awardee must submit a request for public release to the PRC and include the following information: 1) Document Information: document title, document author, short plain-language description of technology discussed in the material (approx. 30 words), number of pages (or minutes of video) and document type (briefing, report, abstract, article, or paper); 2) Event Information: event type (conference, principle investigator meeting, article or paper), event date, desired date for DARPA's approval; 3) DARPA Sponsor: DARPA Program Manager, DARPA office, and contract number; and 4) Contractor/Awardee's Information: POC name, e-mail and phone. Allow four weeks for processing; due dates under four weeks require a justification. Unusual electronic file formats may require additional processing time. Requests can be sent either via e-mail to prc@darpa.mil or via 3701 North Fairfax Drive, Arlington VA 22203-1714, telephone (571) 218-4235. Refer to http://www.darpa.mil/NewsEvents/Public_Release_Center/Public_Release_Center.aspx for information about DARPA's public release process.

Security & Proprietary Issues

NOTE: If proposals are classified, the proposals must indicate the classification level of not only the proposal itself, but also the anticipated award document classification level.

The Government anticipates proposals submitted under this BAA will be unclassified. However, if a proposal is submitted as "Classified National Security Information" as defined by Executive Order 13526, then the information must be marked and protected as though classified at the appropriate classification level and then submitted to DARPA for a final classification determination. Even in cases where the open vehicleforge.mil community generates designs that may otherwise be within the scope of existing classification guidance, pursuant to DoD 5200.1-R §§ C2.3.1.1, C2.3.3, C2.6.1 such resulting designs will be unclassified. Consequently, DARPA will work closely with the FANG performer to ensure that the scope of design crowd-sourcing is carefully tailored.

Security classification guidance via a DD Form 254, "DoD Contract Security Classification Specification," will not be provided at this time, since DARPA is soliciting ideas only. After reviewing the incoming proposals, if a determination is made that the award instrument may result in access to classified information, a DD Form 254 will be issued and attached as part of the award.

Proposers choosing to submit a classified proposal from other classified sources must first receive permission from the respective Original Classification Authority in order to use their information in replying to this BAA. Applicable classification guide(s) should also be submitted to ensure the proposal is protected at the appropriate classification level.

Classified submissions shall be appropriately and conspicuously marked with the proposed classification level and declassification date. Submissions requiring DARPA to make a final classification determination shall be marked as follows:

CLASSIFICATION DETERMINATION PENDING. Protect as though classified (insert the recommended classification level: (e.g., Top Secret, Secret or Confidential)

Classified submissions shall be in accordance with the following guidance:

Confidential and Secret Collateral Information: Use classification and marking guidance provided by previously issued security classification guides, the Information Security Regulation (DoD 5200.1-R), and the National Industrial Security Program Operating Manual (DoD 5220.22-M) when marking and transmitting information previously classified by another Original Classification

Authority. Classified information at the Confidential and Secret level may be submitted via ONE of the two following methods:

1. Hand-carried by an appropriately cleared and authorized courier to the DARPA CDR. Prior to traveling, the courier shall contact the DARPA CDR at 703-526-4052 to coordinate arrival and delivery.

OR

2. Mailed via appropriate U.S. Postal Service methods (e.g., (USPS) Registered Mail or USPS Express Mail). All classified information will be enclosed in opaque inner and outer covers and double wrapped. The inner envelope shall be sealed and plainly marked with the assigned classification and addresses of both sender and addressee.

The inner envelope shall be addressed to:

Defense Advanced Research Projects Agency
ATTN: TTO
Reference: BAA-12-15
3701 North Fairfax Drive
Arlington, VA 22203-1714

The outer envelope shall be sealed with no identification as to the classification of its contents and addressed to:

Defense Advanced Research Projects Agency
Security & Intelligence Directorate, Attn: CDR
3701 North Fairfax Drive
Arlington, VA 22203-1714

All Top Secret materials: Top Secret information should be hand carried by an appropriately cleared and authorized courier to the DARPA CDR. Prior to traveling, the courier shall contact the DARPA CDR at 703-526-4052 to coordinate arrival and delivery.

Special Access Program (SAP) Information: SAP information must be transmitted via approved methods. Prior to transmitting SAP information, contact the DARPA SAPCO at 703-526-4052 for instructions.

Sensitive Compartmented Information (SCI): SCI must be transmitted via approved methods. Prior to transmitting SCI, contact the DARPA Special Security Office (SSO) at 703-526-4052 for instructions.

Proprietary Data: All proposals containing proprietary data should have the cover page and each page containing proprietary data clearly marked as containing proprietary data. It is the Proposer's responsibility to clearly define to the Government what is considered proprietary data.

Proposers must have existing and in-place prior to execution of an award, approved capabilities (personnel and facilities) to perform research and development at the classification level they propose. It is the policy of DARPA to treat all proposals as competitive information, and to disclose their contents only for the purpose of evaluation. Proposals will not be returned. The original of each proposal received will be retained at DARPA and all other non-required copies destroyed. A certification of destruction may be requested, provided the formal request is received at this office within 5 days after unsuccessful notification.

III. PROPOSAL REQUIREMENTS

Proposals shall be submitted as a single volume following the section structure outlined below. Proposals must be on 8.5 inch x 11 inch plain white paper, in 12 point font, and with 1 inch margins. Smaller font may be used for figures, tables and charts. The inclusion of 11 inch x 17 inch fold-outs for large figures is permitted. Proposals must be in English.

There is no page limit on the length of proposals. However, conciseness and clarity of prose is strongly encouraged. Except in the statement of work and cost proposal which must comport to a certain standard of detail as described below, proposers are encouraged to be succinct. Proposers should, however, be as definitive as possible in their characterization of the proposed effort, providing quantitative characterizations where appropriate, and concretely identifying approaches, tools, equipment, etc. to be employed.

1. Cover Page

   The cover page should include the BAA number (DARPA-BAA-12-15), the name of the proposing organization which would receive the contract (prime performer organization); indicate whether the prime performer is categorized as "large business," "small disadvantaged business," "other small business," "historically black college or university (HBCU)," "minority institution (MI)," "other educational," or "nonprofit"; the names of ALL subcontractor or team member organizations and their categorization; the title of the proposal; a technical and an administrative point of contact for the proposal (which can be the same person) and their title, mailing address, telephone, and e-mail; total proposed cost for the base and each option period; proposal validity period (minimum 120 days); affirmation that the proposing organization and individual team members are not providing scientific, engineering, and technical assistance (SETA) or similar support to any DARPA technical office(s) through an active contract or subcontract; affirmation that there is no animal or human use research in the proposed effort.

2. Technical Approach

   This section should provide a detailed description of the proposed technical approach to the problem outlined in this BAA. Proposers should provide an overview of the overarching philosophy, as well as approach to integration across the various tasks in subsection 2.0, followed by subsections 2.1, 2.2, 2.3, 2.4, and 2.5, each corresponding to tasks 1 through 5, respectively, as described in this BAA. For each task, proposers should identify their approach to supporting each of the three challenges. Recognizing that many of the underlying enabling technologies for the FANG are high-risk research efforts, this section should lay out the proposer's risk mitigation strategy, and in particular their approach to substituting lower-risk techniques where success of research efforts is not attained on the aggressive timeline required of the program. Additional subsections and appendices may be added to this section as needed, for instance, to provide lists and capabilities of equipment for purchase, additional activities that the proposer deems essential for achieving the objectives of this BAA, etc. Conciseness is strongly encouraged.

3. Intellectual Property Approach

This section of the proposal should detail the proposer's intellectual property approach. As described in this BAA, DARPA desires Unlimited Rights to all deliverables generated by the FANG performer under this effort except clearly-identified, widely-available, commercial software tools, with their commercial availability described and substantiated in the proposal. Proposers must document in this section any data or software that will be delivered with less than Unlimited Rights, including commercial data or software, in the following format as prescribed by DFARS 252.227-7013, Rights in Technical Data--Noncommercial Items, DFARS 252.227-7014, Rights in Noncommercial Computer Software and Noncommercial Computer Software Documentation, and DFARS 252.227-7015, Technical Data--Commercial Items:

Technical Data or Computer Software to Be Furnished with Restrictions or That Is Commercial	Summary of Intended Use in the Course of Performance	Basis for Assertion	Asserted Rights Category	Name of Person Asserting Restrictions
(LIST)	(NARRATIVE)	(LIST)	(LIST)	(LIST)

Proposers need not include in the table above third-party technical data or software which is handled in the course of collecting models, designs, etc. from FANG Challenge participants. However, proposers should describe in this section of their proposal their approach to ensuring that the government receives at least Government Purpose Rights (GPR) (which may be provided without reversion to Unlimited Rights after five years) to FANG Challenge participant designs. Proposers should also describe their approach, measures, and controls which they propose to utilize to safeguard third-party proprietary information belonging to FANG Challenge participants from inadvertent disclosure while in the proposer's custody. Finally, proposers must provide a good-faith representation that they either own or possess appropriate licensing rights to all other intellectual property that will be utilized in the course of performance of the proposed effort.

4. Management Approach

This section should describe the proposer's team and how it will be managed in the course of performance. An organizational chart should be included, noting any relationships with subcontractors, independent consultants, major vendors, and any other external parties on whom the proposer will rely in the course of performance.[14] The nature of the relationship should be described in some detail, including any legal instruments (contracts, purchase orders, teaming agreements, etc.), their status as of the time of the proposal (envisioned, pending negotiation, in place, etc.), and key provisions that substantively affect the allocation of cost, schedule, and performance risk between the proposer and the counterparty. Any other notable attributes or aspects of the proposer's management approach should be described in this section. Letters of commitment and any other relevant documentation may be included as appendices to this section.

5. Key Personnel

This section should identify by name the key personnel that the proposer is committing to use if selected for award. Note that these personnel will be identified by name in the resultant contract and DARPA will monitor their level of effort in the course of performance based on monthly personnel hours reports described in the BAA section on deliverables. Proposers should not propose personnel whom they do not intend to employ on the contract. This section should include brief biographies, including education and work history, of key personnel and especially describe the

[14] Do not forget that an exhaustive list of all subcontractors, consultants, and major vendors must also be supplied on the cover page of the proposal.

individual's experience and past performance on efforts that are relevant to their qualification for FANG. Additionally, proposers should supply a table indicating the level of effort in terms of hours to be expended by each key person during each calendar year of the effort and other (current and proposed) major sources of support for them and/or commitments of their efforts. DARPA expects all key personnel associated with a proposal to make substantial time commitment to the proposed activity and the proposal will be evaluated accordingly.

Include a table of key individual time commitments as follows:

Individual	Project	Pending/Current	CY 2012	CY 201X
Jane Doe	FANG	Proposed	Y hours	Z hours
	Project A	Current	Y hours	Z hours
	Project B	Pending	Y hours	Z hours
John Deer	FANG	Proposed	Y hours	Z hours

6. Schedule & Major Milestones

This section should depict an integrated master schedule for the proposed effort depicting major milestones, deliverables, and dependencies between tasks. A critical schedule path should be depicted and tasks/events on the critical schedule path should be identified and described. The schedule should be relative to the date of contract award. Measurable milestones should capture key development points in tasks and should be clearly articulated and defined in time relative to start of effort.

7. Statement of Work (SOW) to Be Performed

The SOW should include a list of tasks that the awardee will accomplish in the course of contract performance if awarded under this solicitation. Major task categories should correlate to the tasks listed in the BAA, but additional tasks may (and should) be included and the overall organization scheme for the SOW is at the discretion of the proposer. The tasks should be discrete activities with clear delineation of scope, responsibility, schedule, and outcome. Each task should be described with an imperative statement ("The performer shall do X, Y, Z…"), followed by an elaboration of the scope of the task, who will perform the task (responsible organization and individuals), when it will be commenced and concluded, and what the concrete outcome or deliverable of the task will be. There is no limit on the length of the SOW, but 2-3 pages of single-spaced narrative per $1 million in proposed cost is offered as an advisory guideline. The SOW must begin and end on a new page and each page of the SOW must not contain any restrictive markings such as Proprietary, Competition Sensitive, etc. as the SOW will be incorporated in the award instrument if the proposal is selected.

8. Cost

This section should delineate the proposed costs by task as listed in the SOW. For each task, the cost should be broken out by major cost category (direct labor; materials; travel; other direct costs, overhead charges, etc.) and a basis of estimate and rationale should be supplied for each task and cost category. Labor categories and hourly personnel costs must be identified. Note that this information must be supplied for all team members, including any subcontractors, consultants, etc. Bills of materials and vendor price quotes must be included to substantiate any purchases of materials, equipment, or other direct costs. For major expenditures, evidence of competitive vendor selection should be included. A cost summary by team member and major vendor should be included. Overall cost should also be broken down by month relative to the award date (i.e., award+1 month, +2 months, etc.).[15] The source, nature, and amount of any cost-sharing should be separately documented. Any profit or fee should be explicitly detailed and justified.[16] Finally, on the last page of the cost proposal, the proposer should provide, where known, the name and contact information for their cognizant Defense Contract Management Agency (DCMA) and Defense Contract Audit Agency (DCAA) officials, the proposer's official business address, the address(es) where performance will take place, commercial and government entity (CAGE) code, taxpayer identification number (TIN), and DUNS number.

Proposers should submit two (2) hard copies of their proposal and two (2) CD-ROMs containing the entire proposal as a single Adobe PDF file to the following address:

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[15] To summarize and restate, three separate cost views should be included in the cost proposal. Costs should be broken down: (1) by each SOW task and cost category; (2) by team member including subcontractors, consultants, and vendors; and (3) by month of performance with sums for the base period and each option period. The first view must be substantiated with bases of estimate and vendor quotes for each task and cost category.

[16] Note that FANG Challenge prizes will be awarded to the winner directly by DARPA and should not be included in the offeror's cost proposal.

DARPA/TTO
Attn: Paul Eremenko, DARPA-BAA-12-15
3701 North Fairfax Drive
Arlington, VA 22203

No e-mailed or faxed proposals will be accepted. The deadline for submissions is 1400 (2:00pm) Eastern Time on Friday, February 17, 2012. The closing date for this BAA is 1400 (2:00pm) Eastern Time on Monday, June 4, 2012. The dates and times indicated are deadlines by which proposals must be received by DARPA.

Proposers are required to submit proposals by the time and date specified in the BAA in order to be considered during the initial round of selections. DARPA may evaluate proposals received after this date for a period up to one year from date of posting on FedBizOpps. Ability to review late submissions remains contingent on availability of funds.

IV. PROPOSAL EVALUATION CRITERIA

Evaluation of proposals will be accomplished through a scientific/technical review of each proposal. Proposals will not be evaluated against each other since they are not submitted in accordance with a common statement of work (SOW). DARPA's intent is to review proposals as soon as possible after they arrive; however, proposals may be reviewed periodically for administrative reasons. Proposals will be evaluated using the following criteria, listed in descending order of importance:

1. Overall Scientific and Technical Merit:
The proposed technical approach is feasible, achievable, complete and supported by a proposed technical team that has the expertise and experience to accomplish the proposed tasks. The soundness and innovativeness of proposed technical approach, the flexibility of proposed approach to accommodate technical uncertainty, and the likelihood of technical success of proposed technical approach will be evaluated.

2. Potential Contribution and Relevance to the DARPA Mission:
The potential contributions of the proposed effort with relevance to the national technology base will be evaluated. Specifically, DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their application. The proposal will also be evaluated based on a demonstrated understanding of DARPA's goals for the FANG program and the likelihood of successful integration of proposed effort into the overarching Adaptive Vehicle Make portfolio.

3. Potential to Accomplish Technology Transition:
The proposal will be evaluated on the extent to which proposed intellectual property approach will support open source promulgation and other avenues of technology transition for selected deliverables. Additionally, the alignment of proposed effort with the proposer's commercial business model will be evaluated.

4. Credibility of Proposer's Team:
The proposal will be evaluated on the qualifications and commitment levels of key personnel, the extent and soundness of teaming or other organizational relationships, and individual and organizational experience with comparable efforts.

5. Cost Realism:

The objective of this criterion is to establish that the proposed costs are realistic for the technical and management approach offered, as well as to determine the proposer's practical understanding of the effort. The proposal will be reviewed to determine if the costs proposed are based on realistic assumptions, reflect a sufficient understanding of the technical goals and objectives of the BAA, and are consistent with the proposer's technical approach (to include the proposed SOW). At a minimum, this will involve review, at the prime and subcontract level, of the type and number of labor hours proposed per task as well as the types and kinds of materials, equipment and fabrication costs proposed.

Award will be made to the proposer whose proposal is determined to be the most advantageous to the government, all factors considered, including the potential contributions of the proposed work to the overall research program and the availability of funding for the effort.

It is the policy of DARPA to ensure impartial, equitable, comprehensive proposal evaluations and to select the source (or sources) whose offer meets the government's technical, policy, and programmatic goals. Pursuant to FAR 35.016, the primary basis for selecting proposals for acceptance shall be technical, importance to agency programs, and funds availability. In order to provide the desired evaluation, qualified government personnel will conduct reviews and (if necessary) convene panels of experts in the appropriate areas.

Restrictive notices notwithstanding, proposals may be handled for administrative purposes by support contractors. These support contractors are prohibited from competition in DARPA technical research and are bound by appropriate non-disclosure requirements.

Subject to the restrictions set forth in FAR 37.203(d), input on technical aspects of the proposals may be solicited by DARPA from non-government consultants/experts who are strictly bound by appropriate conflict of interest and non-disclosure requirements.

It is the policy of DARPA to treat all proposals as competitive information and to disclose their contents only for the purpose of evaluation. No proposals will be returned. After proposals have been evaluated and selections made, electronic copies of each proposal received will be retained at DARPA and all other copies will be destroyed.

V. ELIGIBILITY INFORMATION & ADDITIONAL REQUIREMENTS

Eligibility & Conflicts of Interest

FANG performers and their employees, if successfully selected and awarded a contract in response to this BAA, will not be eligible to receive prizes or independently assert intellectual property rights for IFV design submissions to FANG Challenges. In other words, a personal and organizational conflict of interest will exist between being a FANG performer and being an eligible participant in the FANG Challenge prize competitions.

There are no restrictions on FANG proposers contacting or teaming with existing performers on the META, iFAB, iFAB Foundry, *vehicleforge.mil*, or other AVM portfolio efforts.

Without prior approval or a waiver from the DARPA Director, in accordance with FAR 9.503, an awardee cannot simultaneously provide scientific, engineering, technical assistance (SETA) or similar support and also be a technical performer. Therefore, all proposers as well as proposed subcontractors and consultants must affirm whether they (their organizations and individual team members) are providing SETA or similar support to any DARPA technical office(s) through an active contract or subcontract. All affirmations must state which office(s) the proposer, subcontractor, consultant, or individual supports and identify the prime contract number(s). Affirmations shall be furnished at the time of proposal submission. All facts relevant to the existence or potential existence of organizational conflicts of interest (FAR 9.5) must be disclosed. The disclosure must include a description of the action the proposer has taken or proposes to take to avoid, neutralize, or mitigate such conflict. If in the sole opinion of the government after full consideration of the circumstances, a proposal fails to fully disclose potential conflicts of interest and/or any identified conflict situation cannot be effectively mitigated, the proposal will be rejected without technical evaluation and withdrawn from further consideration for award.

If a prospective proposer believes that any conflict of interest exists or may exist (whether organizational or otherwise) or has questions on what constitutes a conflict of interest, the proposer should promptly raise the issue with DARPA by sending his/her contact information and a summary of the potential conflict to the DARPA-BAA-12-15@darpa.mil mailbox before time and effort are expended in preparing a proposal and mitigation plan.

All responsible sources capable of satisfying the Government's needs may submit a proposal that shall be considered by DARPA. Historically Black Colleges and

Universities (HBCUs), Small Businesses, Small Disadvantaged Businesses and Minority Institutions (MIs) are encouraged to submit proposals and join others in submitting proposals; however, no portion of this announcement will be set aside for these organizations' participation due to the impracticality of reserving discrete or severable areas of this research for exclusive competition among these entities.

Federally Funded Research and Development Centers (FFRDCs) and government entities (government/national laboratories, military educational institutions, etc.) are subject to applicable direct competition limitations and cannot propose to this solicitation in any capacity unless they address the following conditions. FFRDCs must clearly demonstrate that the proposed work is not otherwise available from the private sector AND must also provide a letter on letterhead from their sponsoring organization citing the specific authority establishing their eligibility to propose to government solicitations and compete with industry, and compliance with the associated FFRDC sponsor agreement and terms and conditions. This information is required for FFRDCs proposing to be prime or subcontractors. Government entities must clearly demonstrate that the work is not otherwise available from the private sector and provide written documentation citing the specific statutory authority (as well as, where relevant, contractual authority) establishing their ability to propose to government solicitations. At the present time, DARPA does not consider 15 U.S.C. § 3710a to be sufficient legal authority to show eligibility. While 10 U.S.C. § 2539b may be the appropriate statutory starting point for some entities, specific supporting regulatory guidance, together with evidence of agency approval, will still be required to fully establish eligibility. DARPA will consider eligibility submissions on a case-by-case basis; however, the burden to prove eligibility for all team members rests solely with the proposer.

Current federal employees are prohibited from participating in particular matters involving conflicting financial, employment, and representational interests (18 U.S.C. §§ 203, 205, and 208). The DARPA Program Manager for this solicitation is Paul Eremenko and the Deputy Program Manager is LTC Nathan Wiedenman. Once the proposals have been received, and prior to the start of proposal evaluations, the government will assess potential conflicts of interest and will promptly notify the proposer if any appear to exist. (Please note, the government assessment does NOT affect, offset, or mitigate the proposer's own duty to give full notice and planned mitigation for all potential organizational conflicts, as discussed above.)

Animal & Human Use

All research involving human subjects, to include use of human biological specimens and human data, selected for funding must comply with the federal regulations for human subject protection. Further, research involving human subjects that is conducted or supported by the DoD must comply with 32 CFR 219, *Protection of Human Subjects* http://www.access.gpo.gov/nara/cfr/waisidx_07/32cfr219_07.html) and DoD Directive 3216.02, *Protection of Human Subjects and Adherence to Ethical Standards in DoD-Supported Research* (http://www.dtic.mil/whs/directives/corres/pdf/321602p.pdf).

Institutions awarded funding for research involving human subjects must provide documentation of a current Assurance of Compliance with Federal regulations for human subject protection, for example a Department of Health and Human Services, Office of Human Research Protection Federal Wide Assurance (http://www.hhs.gov/ohrp). All institutions engaged in human subject research, to include subcontractors, must also have a valid Assurance. In addition, personnel involved in human subjects research must provide documentation of completing appropriate training for the protection of human subjects.

For all proposed research that will involve human subjects in the first year or phase of the project, the institution must provide evidence of or a plan for review by an Institutional Review Board (IRB) upon final proposal submission to DARPA. The IRB conducting the review must be the IRB identified on the institution's Assurance. The protocol, separate from the proposal, must include a detailed description of the research plan, study population, risks and benefits of study participation, recruitment and consent process, data collection, and data analysis. Consult the designated IRB for guidance on writing the protocol. The informed consent document must comply with federal regulations (32 CFR 219.116). A valid Assurance along with evidence of appropriate training all investigators should all accompany the protocol for review by the IRB.

In addition to a local IRB approval, a headquarters-level human subjects regulatory review and approval is required for all research conducted or supported by the DoD. The Army, Navy, or Air Force office responsible for managing the award can provide guidance and information about their component's headquarters-level review process. Note that confirmation of a current Assurance and appropriate human subjects protection training is required before headquarters-level approval can be issued.

The amount of time required to complete the IRB review/approval process may vary depending on the complexity of the research and/or the level of risk to study participants. Ample time should be allotted to complete the approval process. The IRB approval process can last between one to three months, followed by a DoD review that could last between three to six months. No DoD/DARPA funding can be used towards human subjects research until ALL approvals are granted.

Any Recipient performing research, experimentation, or testing involving the use of animals shall comply with the rules on animal acquisition, transport, care, handling, and use in: (i) 9 CFR parts 1-4, Department of Agriculture rules that implement the Laboratory Animal Welfare Act of 1966, as amended, (7 U.S.C. 2131-2159); (ii) the guidelines described in National Institutes of Health Publication No. 86-23, "Guide for the Care and Use of Laboratory Animals"; (iii) DoD Directive 3216.01, "Use of Laboratory Animals in DoD Program."

For submissions containing animal use, proposals should briefly describe plans for Institutional Animal Care and Use Committee (IACUC) review and approval. Animal studies in the program will be expected to comply with the PHS Policy on Humane Care and Use of Laboratory Animals, available at http://grants.nih.gov/grants/olaw/olaw.htm.

All Recipients must receive approval by a DoD certified veterinarian, in addition to an IACUC approval. No animal studies may be conducted using DoD/DARPA funding until the USAMRMC Animal Care and Use Review Office (ACURO) or other appropriate DoD veterinary office(s) grant approval. As a part of this secondary review process, the Recipient will be required to complete and submit an ACURO Animal Use Appendix, which may be found at https://mrmc-www.army.mil/index.cfm?pageid=Research_Protections.acuro&rn=1.

If a potential proposer envisions the need for human or animal use, the proposer should promptly raise the issue with DARPA by sending his/her contact information and a summary of the potential human or animal use to the DARPA-BAA-12-14@darpa.mil mailbox for further instructions. Failure to notify DARPA of planned human or animal use prior to submission of a proposal may result in the proposal being disqualified from review.

Miscellaneous Statutory Requirements

Unless the proposer is exempt from this requirement, as per FAR 4.1102 or 2 CFR § 25.110 as applicable, all proposers must be registered in the Central Contractor Registration (CCR) and have a valid Data Universal Numbering System (DUNS) number prior to submitting a proposal. Information on CCR registration is available at http://www.ccr.gov. All proposers must maintain an active CCR registration with current information at all times during which they have an active federal award or proposal under consideration by DARPA. All proposers must provide the DUNS number in each proposal they submit. DARPA cannot make an assistance award to a proposer until the proposer has provided a valid DUNS number and has maintained an active CCR registration with current information.

As per FAR 22.1802, recipients of FAR-based procurement contracts must enroll as Federal Contractors in E-verify and use E-Verify to verify employment eligibility of all employees assigned to the award. All resultant contracts from this solicitation will include FAR 52.222-54, Employment Eligibility Verification. This clause will not be included in Other Transactions or contracts.

The FAR clause 52.204-10, "Reporting Executive Compensation and First-Tier Subcontract Awards," will be used in all procurement contracts valued at $25,000 or more. A similar award term will be used in all cooperative agreements.

FAR 52.209-9, Updates of Publicly Available Information Regarding Responsibility Matter, will be included in all contracts valued at $500,000 where the contractor has current active Federal contracts and grants with total value greater than $10,000,000.

In accordance with FAR 4.1201, proposers will be required to complete electronic annual representations and certifications at http://orca.bpn.gov prior to contract award.

Intergovernmental review and funding restrictions are not applicable.

APPENDIX 1:
PHILOSOPHICAL UNDERPINNINGS OF ADAPTIVE VEHICLE MAKE

Introduction

At DARPA, we say that *to innovate, we must make* and *to protect, we must produce.* These words ring true to most private-sector entrepreneurs, but they are increasingly anathema to the way we do business in defense. Historical as well as present-day examples of disruptive innovations--from Pasteur, to Kalashnikov, to Kilby--are almost invariably predicated on discoveries and refinements made in the course of manufacture. And while the epicenter of battle may be increasingly shifting into the digital domain, the defense of flesh, blood, and territory is still the culmination of modern warfare. Tanks, airplanes, ships, and satellites--systems made of atoms as well as bits--are in no danger of disappearing from the battlefield in the foreseeable future. Increasingly, however, such next generation systems are born, live, and die as little more than figments of PowerPoint. To put it another way, *vision without execution is day-dreaming.* And day-dreaming is of little use to the warfighter.

Norm Augustine, in his "Final Law of Economic Disarmament," plots aircraft unit costs versus time since the advent of aviation.[17] Upon projection into the future, the lamentable trend suggests that by the year 2054 the entire U.S. defense budget will purchase just one aircraft.[18] And while we must remain wary of falling into the Malthusian fallacy of extrapolating exponentials into the indefinite future, the fact remains that program after program we have hewed close to the trend line. The number of major system new starts across every domain of military systems has dwindled to fewer than one per decade,[19] and correspondingly, the number of major system manufacturers barely scrapes by for an oligopoly. If the imperatives in the first sentence of this paper hold true, then we are in trouble.

Augustine's law is correlative, but tells us little about causality. The single biggest driver behind increased aircraft costs has been schedule growth, and the principal cause of schedule growth is increasing product complexity.[20] This

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[17] N.R. Augustine, *Augustine's Laws*, American Institute of Aeronautics & Astronautics, Reston, VA, 6th ed., 1997, pp. 104-110.
[18] As Augustine, *ibid.*, and others point out, the same trend with slightly different exponentials holds true in other system domains such as ships, satellites, and military ground vehicles. See, e.g., M.V. Arena, I. Blickstein, et al., *Why Has the Cost of Navy Ships Risen?*, Report No. MG-484, RAND Corporation, Santa Monica, CA, 2006.
[19] For aircraft, see, e.g., P.S. Antón, E.C. Gritton, et al., *Wind Tunnel and Propulsion Test Facilities*, Report No. MG-178, RAND Corporation, Santa Monica, CA, 2004, pp. 14-15.
[20] A recent RAND report attributes approximately half of the escalation in fighter aircraft costs between 1975 and 2005 to schedule growth associated with increased complexity. M.V. Arena, O.

causal chain runs in the face of much conventional wisdom--that the bureaucracy is getting increasingly dysfunctional, that the acquisition system is becoming more and more byzantine, and that the talents of the program management cadre are atrophying. We do not dispute the actuality or acuity of any of these phenomena. DARPA, however, is a technology organization and the roots of this problem are fundamentally technological. There is also a long history of disruptive technological solutions precipitating rapid policy reform.

Military aerospace systems have sustained approximately a three to four order of magnitude increase in complexity over the past half-century. Commensurately, their development timelines grew from an average of 36 to 48 months, to 12-15 years today. The projection for next-generation systems is one to two additional orders of magnitude in complexity growth, with development timelines potentially reaching two decades. And while some of the increased complexity is undoubtedly gratuitous (an artifact of inefficient design), most of it is driven by a drive toward increased connectivity, efficiency, safety, and performance (probably in that order).

The phenomenology of complex systems is characterized--across systems in every domain: biological, financial, computational, and engineered alike--by unanticipated interactions, emergent behaviors, and occasional catastrophic cascading failures. In engineered systems, the discipline of systems engineering was devised with the express goal of decomposing the system into humanly-tractable design problems, and managing the interactions throughout the system as the individually-designed pieces are integrated.

Systems engineering was originally developed by Simon Ramo of the Ramo-Woolridge Corporation (subsequently TRW), under the tutelage of Gen. Bernard Schriever, in the course of designing and building the Atlas ICBM.[21] The systems engineering approach was vigorously applied and refined in the course of Apollo. It was subsequently codified in 1969 as MIL-STD-499A. Remarkably, the methodology is largely unchanged today. With the exception of tools that expedite certain steps in the process, the process as a whole is very much as it was a half-century prior.

A stylized depiction of the systems engineering process is the so-called "V." The downward portion of the V corresponds to the decomposition of the system along functional groups, and the flow-down and allocation of requirements as the system is decomposed. The cleavage lines for this decomposition process are disciplinary stovepipes--there is nothing fundamental or optimal about the

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Younossi, et al., *Why Has the Cost of Fixed-Wing Aircraft Risen?*, Report. No. MG-696, RAND Corporation, Santa Monica, CA, 2008, p. xvii.

[21] T.P. Hughes, *Rescuing Prometheus*, Pantheon Books, New York, NY, 1998, pp. 69-139.

breakdown of the system except that the functional stovepipes correspond to the manner in which we train engineers. Once the system is decomposed to the component level, requirements are allocated, and components are optimally designed to meet these requirements.

The upward-sloping portion of the V is the subsequent composition--or integration--process. Components are assembled, integrated, and tested. Inevitably, unanticipated interactions emerge in the course of integration. It is the systems engineer's principal occupation at this point in the process to "chase" and try to anticipate these interactions before they manifest themselves in the laboratory or on the factory floor. She is destined to fail, however, since the number of interactions scales exponentially with the number of components; cyber-physical interactions add a layer of complexity beyond that. And so, inevitably, a re-design cycle begins. In fact, the two sides of the V are ever more interconnected with increasingly frequent re-designs. This re-design in the course of integration is the principal cause of schedule growth in modern complex military systems.[22] The problem of complexity is more insidious than that, however. The number of possible states and configurations of a modern aircraft, for instance, vastly exceeds our ability to test them exhaustively. The test timeline is increasingly itself a major driver of development schedules. Yet today's systems engineering lore is replete with stories of discovering fundamental design flaws in the newest fighter jet its first time on the runway.

Why hasn't the systems engineering approach been reinvented to better cope with increasing product complexity? The answer probably lies in a peculiar trait of the defense industry: it is the only industry in which the product is bought before it is ever made. In virtually every other industry the seller makes the product before the consumer buys it. The seller therefore has a strong incentive to control for time in the development process; in defense, he does not.[23]

Existence Proof

Aerospace and defense systems are not unique in their inexorable complexity growth. In fact, technological progress is almost ubiquitously exponential.[24] One industry in particular, however, stands out for its ability to sustain a dramatic increase in product complexity while maintaining development timelines completely constant. That industry is integrated circuits.

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[22] M. Giffin, O. de Weck, et al., "Change Propagation Analysis in Complex Technical Systems," *Journal of Mechanical Design*, Vol. 131, No. 8, Aug. 2009, p. 13.
[23] The perverse incentives of cost-plus contracting and the removal of competitive schedule pressure by rigid acquisition plans surely have something to do with it also.
[24] See, e.g., R. Kurzweil, *The Singularity Is Near*, Viking, 2005 which eloquently describes a myriad of exponential trends in a variety of technology domains.

Moore's Law is a double-edged sword. The good news is that the number of transistors on a chip doubles every 18 months. The bad news, however, is that the number of transistors on a chip *doubles* every 18 months. In other words, product complexity increases rapidly, even as does capability. By the early 1980s, the progenitor and behemoth of the integrated circuit industry was at a critical juncture. On the one hand, Intel's hugely successful "tick-tock" product development strategy set the cadence for the entire computer industry--the market expected a new processor every 24 months.[25] On the other hand, Intel was facing challenges with the development of the 80386 processor. The manual approach to chip design which had been employed since the company's inception relied on designer know-how to do the circuit layout, route the data and power paths, and build and test numerous prototypes at the company's in-house fabrication facilities. The approach was not scaling well to cope with the nearly 300,000 transistors in the 80386. Intel turned to a University of California at Berkeley spin-off called Cadence Design Systems to productize in a set of design tools a fundamentally novel design approach developed by Carver Mead and Lynn Conway in the late 1970s.[26] The approach, called Very Large Systems Integration (VLSI), was predicated on several pivotal insights:

- Raising the level of abstraction on the design process. Enabling the designer to express her functional intent for the product, rather than having to manipulate the design at the transistor or even the logic gate level.

- Giving up component-level optimality in exchange for system-level verifiability and shortened development times. Performance is easily bought back through frequent technology insertion and product refreshes.

- Verifying the design virtually using detailed models, such that it is correct-by-construction. In other words, the very first chip out of the fab is assured to work almost every time.

The proliferation of VLSI design and associated electronic design automation (EDA) tools has enabled the integrated circuit industry to sustain almost four orders of magnitude in product complexity growth since the 80386 to the present day, while maintaining a consistent product development timeline. It also had an interesting effect on industrial structure. The advent of correct-by-construction design, afforded by investment in little more than a software tool suite,

[25] S.R. Shenoy & A. Daniel, *Intel Architecture and Silicon Cadence: The Catalyst for Industry Innovation*, Intel Corp. White Paper, 2006, available at http://tinyurl.com/ticktockpaper (last visited 12 Oct. 2011).
[26] C. Mead & L. Conway, *Introduction to VLSI Systems*, Addison-Wesley, 1980.

eliminated the need for a captive fabrication facility to support design iteration in the course of new product development. By eliminating the barrier-to-entry associated with the capital requirements of owning and operating a fab, it enabled the separation of design from manufacturing and led to the inception of thousands upon thousands of "fab-less" design firms, along with a consolidation and commoditization of manufacturing in large "silicon foundries." The foundries were (and are) programmable fabrication facilities that could rapidly switch from one design to another, enabling efficient production in quantities of one or quantities of millions. The flip side of the foundry construct was that designers had to make their design conform to the fabrication capabilities of the foundry. This was accomplished through a set of formal design rules that could be used to appropriately constrain the design up front.

To many, it seems preposterous to claim that an integrated circuit provides a useful archetype for the design of an aircraft or ground vehicle. To be sure, there are differences. An integrated circuit consists of fairly homogeneous components--nearly identical gates, transistors, and blocks. It is weakly coupled to the environment, such that an assumption of synchrony can be made. Neither of these is true for an aircraft or ground vehicle. On the other hand, in spite of its diminutive size in contrast to, say, an armored vehicle, an integrated circuit has many more interacting components, analogous cyber-physical interaction challenges, and a comparable number of physics domains that must be modeled in the design process. In other words, VLSI design does not solve the design problem for defense systems, but it does provide an instructive template.

A superficially-analogous disaggregation of the value chain in defense manufacturing can be observed among most of the principal aerospace and defense prime contractors in their divestiture of tier-one and lower manufacturing capability. It has, however, been accompanied by neither a comparable increase in innovation, nor exponential growth in product capability, nor decrease in product development timelines. On the contrary, the defense industry has worsened in its performance in each of these areas, arguably because it has never put in place the technological enablers of a truly disaggregated value chain, thereby confining many major defense and aerospace firms to the "purgatory" between the two models.

Portfolio

In 2009, DARPA embarked on a roadmap of investments in manufacturing, totaling an estimated $1 billion over five years.[27] In domain after domain, we saw

[27] R.E. Dugan, *Statement by Director, Defense Advanced Research Projects Agency to the Subcommittee on Emerging Threats and Capabilities, United States House of Representatives*, 1 Mar. 2011, p. 13,

escalating timelines for making products essential to the warfighter, constraining our ability to adapt to the rapidly changing threat environment and adversarial countermeasures. We firmly believe that *controlling for time* is the quintessence of adaptability, enabling adaptation to new geopolitical realities, facilitating the rapid insertion of new technologies, and invigorating innovation. To that end, we have set the goal of dramatically shortening product development timelines in a variety of product domains by applying the same template for managing complexity--raising the level of abstraction in the design process, consciously giving up component-level optimality in exchange for ease of verification, decoupling design and fabrication, and utilizing foundry-style manufacturing. We have applied this paradigm to the making of pharmaceuticals and vaccines, to synthetic biology, to optics, to sensors, and to vehicles.

Making Military Vehicles

With the AVM programs, we seek to mirror the VLSI revolution for the much more heterogeneous class of cyber-electro-mechanical systems that represent the overwhelming majority of Department of Defense (DoD) acquisitions.[28] As a proof of principle and the first controlled experiment at scale, DARPA has partnered with the Marine Corps with an effort to parallel the Amphibious Combat Vehicle (ACV) program of record and produce a heavy, amphibious infantry fighting vehicle called FANG[29] to identical requirements with at least a factor of five compression in the development timeline.

A partial "existence proof" that this goal might be attainable can be found in the experience of one particular aircraft maker. This firm represents perhaps the most faithful adopter of the high-end computer-aided design and manufacturing (CAD/CAM) and product lifecycle management (PLM) tool suites. They have fully embraced the digital master model of its airplanes' geometry as the principal artifact driving design, manufacturing, and product lifecycle sustainment. The digital master model is unique to each aircraft, tagged by tail number, and constantly updated with actual quality assurance/quality control (QA/QC) once a part is manufactured. The digital model is continuously updated to ensure that the design remains geometrically correct, thereby enabling a virtually shim-less production process. The company's production floor resembles a showroom more than a conventional airplane factory; there is no shimming, no drill-and-fill, and an arms-length relationship with the supply

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available at http://www.darpa.mil/WorkArea/DownloadAsset.aspx?id=2929 (last visited 17 Oct. 2011).

[28] We use the term "cyber-electro-mechanical system" to refer to any system that incorporates mechanical, electrical/electronic, and embedded software components. Examples include aircraft, satellites, ships, and ground vehicles.

[29] Fast, Adaptable Next-Generation Ground Vehicle (FANG)

chain for structural components--enforced by strict adherence to the digital model. The aircraft maker claims up to a two-fold reduction in development timelines for the latest generation of airplanes through this strict adherence to the geometric digital master model and the resultant savings in re-design and bespoke manufacturing consequent to a correct-by-construction geometric design. What if this approach could be extended to physics domains and properties other than static structural geometry of a system? This is precisely what the META program aims to do.

The META program is developing an approach for formal semantic integration across existing domain-specific modeling languages to encapsulate the totality of static and dynamic models needed to represent complex cyber-electro-mechanical systems; a set of design tools and metrics for performing design trade-space exploration; and a set of verification tools for stochastic formal verification of large, highly-heterogeneous system designs. The META capability, once complete, promises to:

- Raise the level of abstraction such that the designer need not manipulate the design at the lowest numbered part level, but can operate at varying levels of hierarchical abstraction and model fidelity;
- Develop practical and observable metrics of complexity to augment size, weight, power, and performance in informing design decisions;
- Enable rapid exploration of the design trade-space for high-fidelity requirements trade-offs; and
- Yield detailed system designs that are "correct-by-construction," i.e., probabilistically verified for consistency, multi-mode interactions, and first-order performance characteristics across all the relevant physics domains (including embedded software).

The META tools will be embodied in an open-source research tool chain; an easy-to-use web-based tool with access to cloud-based high-performance computing capabilities aimed at a mass market; and a high-end tool suite based on state-of-the-art commercial PLM capabilities.

If META represents an analogue to EDA tools, then iFAB[30] is the foundry-style manufacturing capability. Once a given design is developed and verified, iFAB aims to take the formal META design representation and automatically configure a digitally programmable manufacturing facility, including the selection of participating manufacturing facilities and equipment, the sequencing of the product flow and production steps, and the generation of computer-numerically-controlled (CNC) machine instruction sets as well as human instructions and

[30] Instant Foundry Adaptive through Bits (iFAB)

training modules. In essence, iFAB seeks to eliminate the learning curve in large-scale manufacturing in quantities of one.

Much like META, iFAB is predicated on detailed formal models representing the capabilities of various manufacturing machines and processes. By mapping these models into the same semantic domain as the vehicle design, iFAB can automatically constrain the design trade space such that designs that are not manufacturable in a given iFAB instantiation are automatically culled. Though we term iFAB a “foundry”--principally to differentiate it from a conventional factory that, at least in the defense world, tends to be a custom facility tailored to a specific product or small set of product variants--in actuality it is mostly an information architecture. Only the final assembly capability needs to be co-located under a single roof in anything resembling a conventional fabrication facility; the rest of iFAB can be geographically distributed and can, in fact, extend across corporate and industrial boundaries, united only by a common model architecture and certain rules of behavior and business practices. The final assembly node of the iFAB facility for infantry fighting vehicles is currently slated to be at Joint Manufacturing & Technology Center at the Rock Island Arsenal.

The substantial time advantage which stands to be gained from META and iFAB is predicated on the existence of detailed models of components, of the environment (contexts), and of manufacturing equipment and processes. In the case of META, these models contain information on every behavior and modality of interaction (static and dynamic) that a component can exhibit, thereby affecting some other part of the system. This requires significantly more information than exists in most present-day component models, which are typically little more than performance curves and interface specifications. It requires a complete characterization of the desired interfaces as well as the undesirable or spurious interactions that a component can have, such as thermal, vibrational, or electromagnetic emissions. The META tools draw on a component model library which can include discrete “catalog” components, “rubber” or parametric component models where scaling behavior can reasonably be predicted, as well as “ghost” or hypothetical components which may not yet exist but could be developed if they prove useful in specific designs or in especially promising swathes of the design trade space.

Although for the purpose of the FANG vehicle, DARPA has embarked on the construction of model libraries through sponsored research, in the long run we envision the development of an industry consortium to promote and incentivize model development. An interesting example of such an incentive scheme is the

European AUTOSAR[31] consortium, which includes automotive OEMs[32] and electronic component suppliers. Component suppliers publish detailed component models in a uniform modeling language to the consortium as a means of marketing their products to the OEMs.

If the analogue to the VLSI paradigm is borne out by META and iFAB, then the decoupling of design and manufacturing promises to open the aperture for innovation by reducing the barrier-to-entry associated with the capital requirements of a captive fabrication facility to support integration and resultant design iteration. This holds the promise of moving the defense industry from dozens of innovators[33] to, perhaps, thousands. However, DARPA has embarked on an experiment to further increase this number by several orders of magnitude; we call this *democratizing innovation*. Our approach is inspired by several DARPA crowd-sourcing experiments. The first, the DARPA Network Challenge (or the Red Balloon Challenge) offered a prize to the first person or team to correctly identify the locations of ten moored, 8-foot, red weather balloons at various fixed locations in the continental United States. The prize was collected in under nine hours by an MIT team that constructed a social network with a geometric referral incentive scheme for divvying up the prize money and aggregating information on balloon locations. The Network Challenge demonstrated the power of large, heterogeneous, loosely aggregated networks of people united by a common incentive structure.

The second, the XC2V[34] design challenge was a prize award offered to a social network of automotive enthusiasts for the best design of a vehicle body for combat reconnaissance and combat delivery & evacuation missions. The social network was equipped with a simple collaboration environment that enabled designers to receive feedback from the crowd and leverage each other's ideas and concepts. The contest yielded over 150 viable designs in a span of six weeks, of which several dozen were deemed extremely innovative by experts from the user community. The XC2V experiment demonstrated the applicability of crowd-sourcing techniques to military missions, the potential for significant timeline compression, and the value of heterogeneity in the innovation talent pool.

[31] AUTomotive Open System ARchitecture (AUTOSAR)

[32] Original Equipment Manufacturers

[33] If we consider that each sector of the defense industry has 3-5 dominant players, with an elite design team for advanced concepts and new products number around a dozens, the total number of brains contributing to the development of next-generation DoD systems numbers fewer than a hundred. Most of these are experienced designers, selected for seniority and perhaps having seen a defense product all the way from concept to fielding in the course of their career (if they are lucky). Unsurprisingly, this arrangement is not conducive to radical innovation and the idea pool is shockingly small given the size and importance of the procurements drawing upon it.

[34] Experimental Crowd-derived Combat-support Vehicle (XC2V)

The third crowd-sourcing experiment, called Foldit, is an online game that challenges users to fold proteins (a notoriously challenging problem). The game has attracted thousands of players and has yielded some scientifically significant results.[35] The game has shown the existence of outlier savants--small numbers of individuals with cognitive ability to fold proteins that is five or more standard deviations above the mean. Interestingly, most of these individuals had no formal background in biochemistry and no other apparent indicia of their hidden talent. We can postulate the existence of such hidden *5σ*-savants in other domains of expertise. It only takes the discovery of a handful of individuals of such outstanding capacity to alter the course of history.

Based on these early lessons in crowd-sourcing, we are developing *vehicleforge.mil*, an open-source collaboration environment to enable crowd-sourcing of military vehicle designs. *vehicleforge* is structured much like open-source software collaboration (or "forge") sites such as *sourceforge.net*. Such collaboration approaches, however, have not been previously applied to the design of physical systems due to the impossibility of change propagation across design elements (e.g., how did a change to one drawing affect an entirely different and superficially unrelated part of the system?) and the challenge of rapidly predicting the impact of design changes on performance (e.g., did a design change improve or worsen performance, or make the system altogether cease to function?). META provides a solution to both of these problems. It serves both to model and propagate all modalities of interaction among components, and to make first-order performance estimates for a system subjected to a given context or environment model. META, in essence, acts as the equivalent of a software compiler for physical systems.

vehicleforge serves as both a model library and design repository, and is replete with features familiar to open-source software developers such as check-in/check-out, version control, design branching, etc. It enables the customization of intellectual property and security access policies for a given design space, and offers reputation-based credentialing and provenance algorithms for users, components, and designs. *vehicleforge* is a treasure trove of interesting policy challenges vis-à-vis export controls, clickwrap licensing of intellectual property, and protection of potentially sensitive details of the design. It confronts us with strategic questions such as: what balance between secrecy and agility provides the greatest competitive advantage to our warfighting capability against conventional and non-conventional adversaries? Nonetheless, if the vulnerability and timelines associated with proprietary versus open source software are any

[35] F. Khatib, F. DiMaio, Foldit Contenders Group, Foldit Void Crushers Group, et al., "Crystal structure of a monomeric retroviral protease solved by protein folding game players," *Nature Structural and Molecular Biology*, Vol. 18, 2011, pp. 1175–1177.

indication, *vehicleforge* promises to make a significant contribution both to the robustness, quality, and timeliness of military vehicle designs.[36]

META, iFAB, and *vehicleforge* are three elements of infrastructure that will be tested at scale in the development of the FANG vehicle. The FANG design will be developed through a series of prize challenges, culminating in a $2 million award for the best total vehicle design. Design submissions must be encoded in the formal META modeling language, but can emanate from traditional defense industry, networks of smaller businesses using *vehicleforge* as a collaboration and integration environment (thus obviating the need for a systems integrator), entirely open crowd-sourced communities, or hybrids of these approaches. Designs are measured against published context/environment models, such that the scoring of winners is an entirely objective process. The use of prize challenges is DARPA's attempt to move closer to a make-before-buy paradigm for the procurement of defense systems, as well as to open the aperture to non-traditional proposers such as loosely-aggregated networks of businesses or individuals. The winning FANG design will be manufactured in iFAB and evaluated against the Marine Corps' ACV prototype in side-by-side operational testing. In the interest of providing a significant incentive beyond the modest prize award to the FANG design community, the ACV program will incorporate the FANG vehicle in its selection of an ACV design for full-rate production.

The final element of the AVM portfolio is an outreach program aimed at high school students. The MENTOR[37] effort will deploy 1,000 3-D printers in various material chemistries to as many schools, network them into a distributed manufacturing capability supported by simple design collaboration tools, and exercise this architecture with a series of challenges to build systems of modest complexity such as simple robots, go-karts, etc. MENTOR seeks to create a microcosm of the greater AVM portfolio in a manner that is accessible to youths so as to inspire a next-generation cadre of manufacturing innovators.

Concluding Thought

Our species' post-Industrial Revolution technological progress can be neatly binned into several epochs. The 19th century was defined by our ability to harvest abundant energy. The 20th century was a century defined by our command of bits, of the world of information. With nascent advances like model-based design synthesis, direct digital manufacturing, and synthetic biology that bridge the divide between bits and atoms, the 21st century promises to be one defined by our mastery of matter.[38] Today, it is primitive. To adapt a Hobbesian metaphor,

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[36] See, e.g., M. Delio, "Linux: Fewer Bugs Than Rivals," *Wired*, 14 Dec. 2004.
[37] Manufacturing Experimentation and Outreach (MENTOR)
[38] Paraphrased from an observation by MIT's Tom Knight.

traditional industrial manufacturing processes are nasty, brutish and long. They are also rigid--it is difficult to adapt them to new requirements. A host of innovations are now being demonstrated that can transform our ability to make things. The issue is whether the complexity of defense systems can be accommodated by these faster, cheaper and more efficacious approaches. DARPA’s work aims to meet this challenge.

APPENDIX 2:
DEPICTION OF THE META-IFAB INTEGRATED TOOL CHAIN

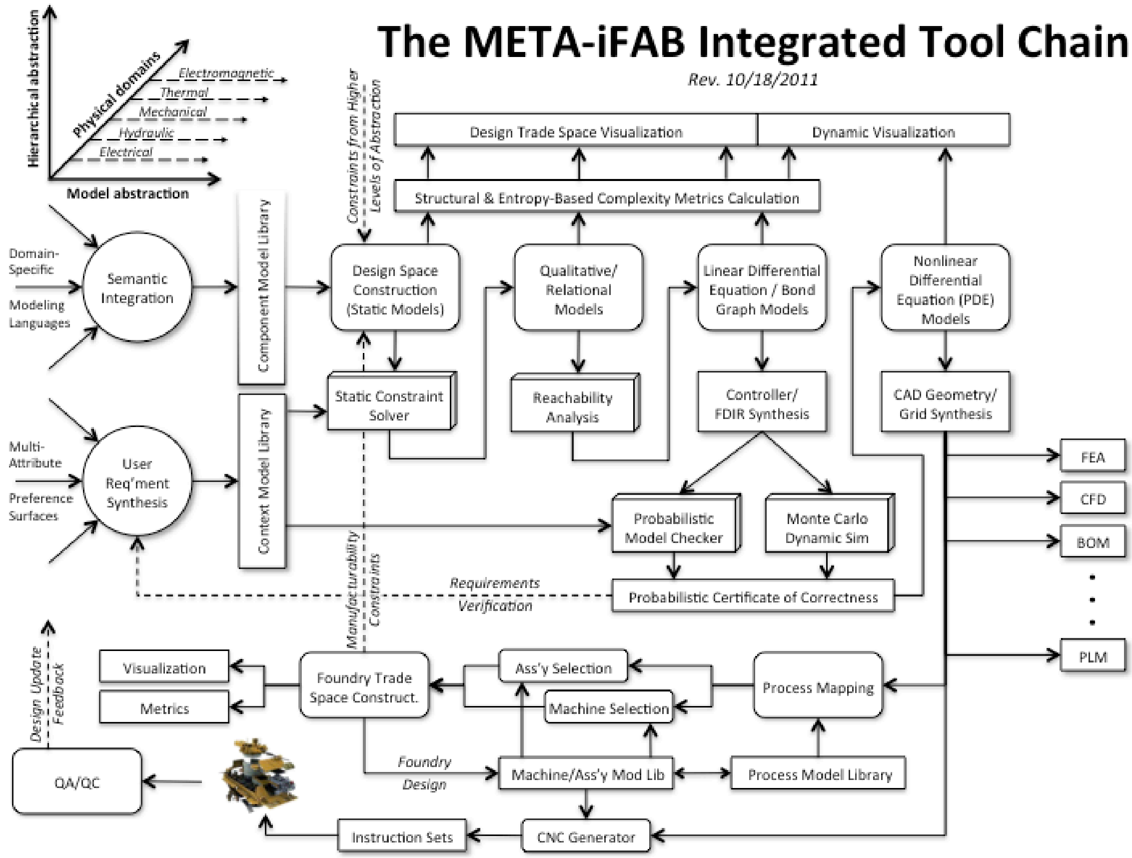

Figure A2.1: The META-iFAB Integrated Tool Chain

The integrated META and iFAB software tool chain, as presently envisioned, is depicted in Figure A2.1 above. The META tools have been under development since Fall 2010 (approximately 12 months as of the time of release of this BAA), although they leverage almost two decades of research in cyber-physical systems and formal verification methods. The META tools are presently at approximately TRL 5-6 and are anticipated to be at TRL 6-7 by the time they must be deployed for the first FANG challenge, with eventual maturation by the time of the Full Vehicle Challenge to TRL 7-8.[39] DARPA is pursuing three parallel instantiations of the META tool chain. The first, the so-called "research core," is being led by Vanderbilt University (in collaboration with MIT, PARC, SRI, and several other partners) and encompasses most of the functionality depicted in Figure A2.1 in a

[39] TRL refers to Technology Readiness Levels as defined in, e.g., *Better Management of Technology Development Can Improve Weapon System Outcomes*, Report No. GAO/NSIAD-99-162, Government Accountability Office, 1999, App. I, available at: http://www.gao.gov/archive/1999/ns991620.pdf

free, open-source implementation. The second, led by a recent spin-off from Xerox PARC called CyDesign Labs, is a highly productized, web-based (software-as-a-service) version aimed at mass market adoption that somewhat reduces the feature set of the research core in exchange of ease of use. The third, led by Dassault Systèmes, is derived from Dassault's existing high-end commercial CAD/PLM tool suite with the addition of probabilistic, simulation-based verification capability across multiple physical domains.

Current iFAB developments, which have been ongoing since Summer 2011, are aimed at several technological challenges that underlie the iFAB concept. These include reasoning about shape, foundry optimization, modeling of humans, and the development of a parametric manufacturing process model library. The iFAB tools presently exist only as a loose aggregation of capabilities supplied by multiple performers without significant integration. Several critical gaps still exist in the end-to-end iFAB functionality, and these are expected to be filled by the iFAB Foundry performer.[40] Principal gaps include the ability to perform kinematic modeling of a broad range of manufacturing machines and processes (including humans), the handling of tolerances in a systematic manner, the homogenization of semantics across various manufacturing process models, and the mechanisms for manufacturability feedback to the META tools. The iFAB tool suite is presently at TRL 3-4 and expected to be rapidly matured to TRL 5-6 by the first FANG challenge, and TRL 7-8 by the Full Vehicle Challenge.

[40] https://www.fbo.gov/spg/ODA/DARPA/CMO/DARPA-BAA-12-14/listing.html

APPENDIX 3:
OPEN SOURCE LICENSE FOR AVM SOFTWARE, MODELS, AND DATA

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APPENDIX 4:
A DESCRIPTION OF THE IFAB/FANG ROCK ISLAND ARSENAL FACILITY

The iFAB Foundry is anticipated to consist of a distributed network of manufacturing nodes connected by the information architecture currently under development (and described in significant detail elsewhere in this BAA). The ultimate target of this distributed network is the assembly of an operational infantry fighting vehicle. The final assembly facility (which can be seen as the last node of the network) will be situated at the Joint Manufacturing Technology Center at the Rock Island Arsenal (JMTC-RIA) in Rock Island, IL (see Figure A4.1). There will be space available to co-locate certain FANG performer equipment, particularly to support FANG BAA Tasks 3 & 4, at this facility.

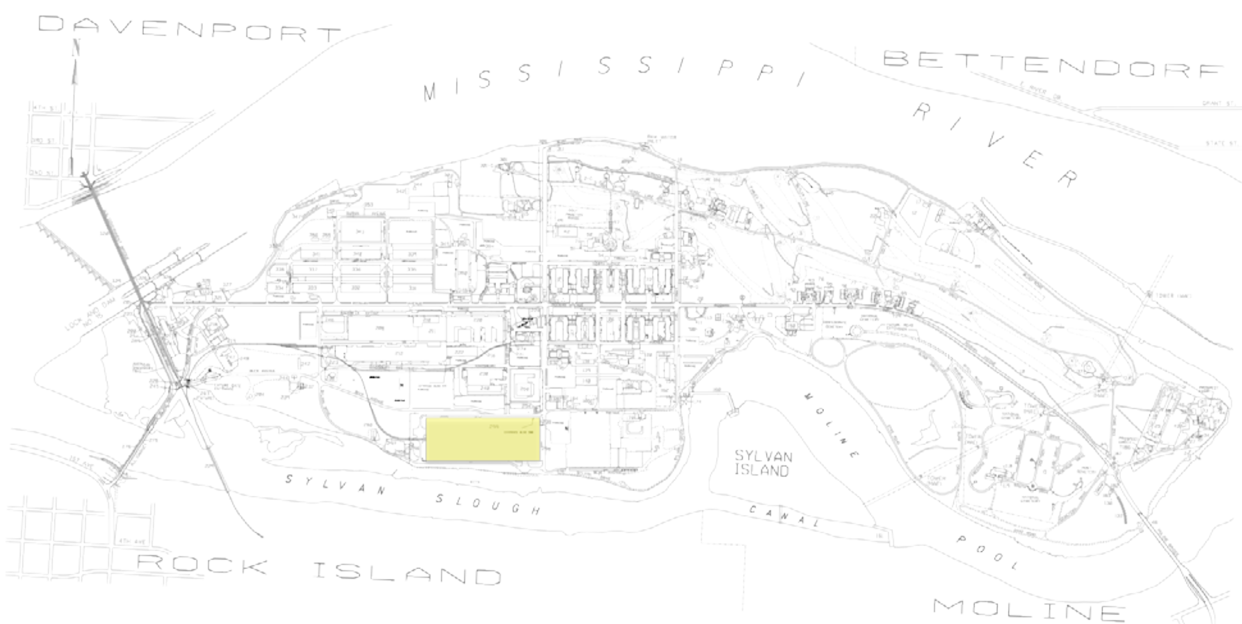

Figure A4.1: Rock Island Arsenal, with Building 299 outlined

The space allotted to DARPA is tentatively planned to be located within Building 299 at JMTC-RIA, a 770,000 sq ft building depicted in Figure A4.2. The iFAB Foundry will occupy approximately 90,000 sq ft of this space. Approximately 45,000 sq ft of space is available to the FANG performer.

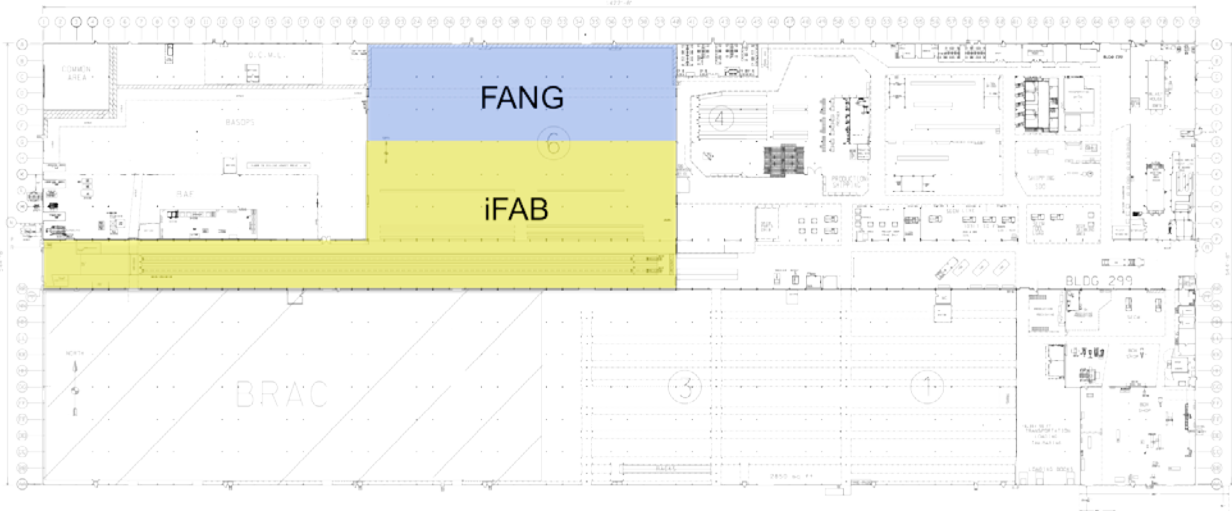

Figure A4.2: Building 299 layout with iFAB Foundry area highlighted in yellow and FANG area in blue

Building 299 has the following characteristics:

Power: All power is currently either standard 110V (lights, utility outlets) or 460V, 3-phase (overhead cranes).
Air: Compressed air available; building currently has a 100-hp compressor with a trim compressor and drying system.
Vertical clearance: Variable with 16 ft minimum
Floor load bearing limits: 1,000 lb/sq ft
Overhead lift capability: Crane capability only exists in the long, lower portion of the iFAB Foundry area shown in Figure A5.2 (an area 780 ft by 60 ft). The western (left) 300 ft of this area has a 75 ton capacity with an existing crane bridge. The rest of this length has a 30 ton capacity, but no currently installed crane bridges.

Within this space, the iFAB performer will instantiate the final assembly node of the iFAB Foundry, with appropriate metrology capacity sufficient to evaluate a full IFV. Separate space will be utilized by the FANG performer for post-production test and evaluation.

The iFAB and FANG performers will be responsible for working with RIA-JTMC and the DARPA management team to oversee necessary facilities modifications/ upgrades, installation of equipment, contractor personnel access to the facility, work scheduling, and logistics associated with shipping and supply of raw materials.

As the RIA-JMTC workforce is highly skilled in multiple areas related to this agreement and RIA-JMTC possesses the requisite statutory authority, RIA-JMTC will make available to proposers government touch labor support to include, but not limited to, assembly, forge, foundry, investment casting, plating, machining, prototyping, testing, production grinding, laser cutting, stamping, and welding. Should a proposer choose to utilize RIA-JMTC staff for on-site touch labor, this must be done through a subcontract to RIA-JMTC. Such labor will not be supplied as government-furnished effort. Furthermore, for purposes of proposal evaluation, the presence or absence of RIA-JMTC as a subcontractor in proposers' efforts will be treated and assessed as any other subcontracted labor. For all inquiries related to subcontracting with RIA-JMTC, the point of contact is Mr. Gary Taylor, Chief of Global Business, (309) 782-5397, gary.f.taylor.civ@mail.mil.

APPENDIX 5:
SAMPLE BILL OF MATERIALS FOR A NOTIONAL IFV

The table below represents a bill of materials (BOM) mapped onto a typical six-level work breakdown structure (WBS) for a notional (hypothetical) infantry fighting vehicle. It is not intended to be a reference design, nor prescriptive in any way. It is meant to serve simply as an example of familiarization for proposers who are not intimately familiar with IFV design.

Table A3.1: Sample BOM for a Notional IFV

0	1	2	3	4	5	6		Identifier
1.1								Vehicle - Infantry Fighting w/RWS
	1.1.1							Drivetrain Subsystem
		1.1.1.1						Powertrain
			1.1.1.1.1					Engine Systems
				1.1.1.1.1.1				Engine
				1.1.1.1.1.2				Engine Mounts & Attachments
				1.1.1.1.1.3				Engine Control System
			1.1.1.1.2					Transmission Systems
				1.1.1.1.2.1				Transmission - hydrostatic
				1.1.1.1.2.2				Transmission filters
				1.1.1.1.2.3				Transmission mounts
				1.1.1.1.2.4				Transmission drive axle
					1.1.1.1.2.4.1			Drive Axle Right Assembly
					1.1.1.1.2.4.2			Drive Axle Left Assembly
				1.1.1.1.2.5				Transmission Controller
				1.1.1.1.2.6				Steering System
					1.1.1.1.2.6.1			Steering Yolk
					1.1.1.1.2.6.2			Steering Controller
			1.1.1.1.3					Fuel System
				1.1.1.1.3.1				Fuel Tank Cells
					1.1.1.1.3.1.1			Lower Fuel Tank Assembly
						1.1.1.1.3.1.1.1		Tank Fill Equipment
						1.1.1.1.3.1.1.2		Tank-mounted Pump
						1.1.1.1.3.1.1.3		Tank Seal/Gasket
						1.1.1.1.3.1.1.4		Tank Mountings
					1.1.1.1.3.1.2			Upper Fuel Tank Assembly

						1.1.1.1.3.1.2.1		Tank Fill Equipment
						1.1.1.1.3.1.2.2		Tank-mounted Pump
						1.1.1.1.3.1.2.3		Tank Seal/Gasket
						1.1.1.1.3.1.2.4		Tank Mountings
				1.1.1.1.3.2				Fuel Transfer Pump
				1.1.1.1.3.3				Fuel Supply Piping
				1.1.1.1.3.4				Fuel Filters
				1.1.1.1.3.5				Fuel Control Switch
				1.1.1.1.3.6				Fuel Level/Flow Sensors
			1.1.1.1.4					Air Intake System
				1.1.1.1.4.1				Air Intake Filter
				1.1.1.1.4.2				Air Intake Filter Housing
				1.1.1.1.4.3				Housing Attachment
				1.1.1.1.4.4				Filter Housing to turbo
				1.1.1.1.4.5				CFM Sensor
			1.1.1.1.5					Exhaust System
				1.1.1.1.5.1				Exhaust Muffler
				1.1.1.1.5.2				Exhaust Muffler Mountings
				1.1.1.1.5.3				Exhaust Piping
				1.1.1.1.5.4				Exhaust Sensing
			1.1.1.1.6					Brake System
				1.1.1.1.6.1				Brake Plate Assembly
					1.1.1.1.6.1.1			Brake Plate Housing
					1.1.1.1.6.1.2			Housing Mountings
				1.1.1.1.6.2				Brake Plates
				1.1.1.1.6.3				Brake Oil Cooling System
					1.1.1.1.6.3.1			Cooling Oil Tank
					1.1.1.1.6.3.2			Cooling Oil Filters
					1.1.1.1.6.3.3			Cooling Oil Piping
					1.1.1.1.6.3.4			Cooling Oil Sensors
					1.1.1.1.6.3.5			Cooling Oil Pump
			1.1.1.1.7					Cooling System
				1.1.1.1.7.1				Cooling System Radiator
				1.1.1.1.7.2				Cooling System Pump
				1.1.1.1.7.3				Cooling System Sensing
				1.1.1.1.7.4				Cooling System Fan
				1.1.1.1.7.5				Cooling System Piping
				1.1.1.1.7.6				Cooling System Control
			1.1.1.1.8					Lubrication System

				1.1.1.1.8.1				Lubrication Oil Tank
				1.1.1.1.8.2				Lubrication Oil Filters
				1.1.1.1.8.3				Lubrication Oil Pumps
				1.1.1.1.8.4				Lubrication Oil Sensing
				1.1.1.1.8.5				Lubrication Oil Piping
				1.1.1.1.8.6				Lubrication System Control
			1.1.1.1.9					Electrical Generation System
				1.1.1.1.9.1				Alternator
				1.1.1.1.9.2				Alternator Drive
				1.1.1.1.9.3				Alternator Mounting
				1.1.1.1.9.4				Alternator Electric Terminals
			1.1.1.1.10					Hydraulic System
				1.1.1.1.10.1				Hydraulic System Tank
				1.1.1.1.10.2				Hydraulic Cooling Radiator
				1.1.1.1.10.3				Main Hydraulic Pump
				1.1.1.1.10.4				Hydraulic Regulation System
					1.1.1.1.10.4.1			Hydraulic System Manifolds
					1.1.1.1.10.4.2			Hydraulic System Valving
					1.1.1.1.10.4.3			Hydraulic System Accumulator
					1.1.1.1.10.4.4			Hydraulic Secondary Reservoir
				1.1.1.1.10.5				Hydraulic System Plumbing
				1.1.1.1.10.6				Hydraulic Filters
				1.1.1.1.10.7				Hydraulic Idler System
					1.1.1.1.10.7.1			Idler Hydraulic Sensing
					1.1.1.1.10.7.2			Idler Hydraulic Control
				1.1.1.1.10.8				Hydraulic Turret Supply System
				1.1.1.1.10.9				Hydraulic Rear Ramp System
					1.1.1.1.10.9.1			Hydraulic Pump
					1.1.1.1.10.9.2			Hydraulic Actuator
					1.1.1.1.10.9.3			Hydraulic Delivery
					1.1.1.1.10.9.4			Hydraulic Sensing
					1.1.1.1.10.9.5			Hydraulic Control
				1.1.1.1.10.10				Hydraulic System Sensing
				1.1.1.1.10.11				Hydraulic System Control
		1.1.1.2						Suspension

			1.1.1.2.1					Suspension Components
				1.1.1.2.1.1				Torsion Bar
				1.1.1.2.1.2				Suspension Arm
				1.1.1.2.1.3				Shock Absorbers
				1.1.1.2.1.4				Suspension Hull Attachment
				1.1.1.2.1.5				Suspension Arm Bolt
				1.1.1.2.1.6				Bearing
			1.1.1.2.2					Wheels
				1.1.1.2.2.1				Drive Idler Inner
				1.1.1.2.2.2				Drive Idler Inner
				1.1.1.2.2.3				Road Wheel - Inner
				1.1.1.2.2.4				Road Wheel - Outer
				1.1.1.2.2.5				Drive Wheel - Inner
				1.1.1.2.2.6				Drive Wheel - Outer
				1.1.1.2.2.7				Track Support Idlers
			1.1.1.2.3					Track
				1.1.1.2.3.1				Track - Left
					1.1.1.2.3.1.1			Track Shoes
					1.1.1.2.3.1.2			Track Pins
					1.1.1.2.3.1.3			Track Connectors
				1.1.1.2.3.2				Track - Right
					1.1.1.2.3.1.1			Track Shoes
					1.1.1.2.3.1.2			Track Pins
					1.1.1.2.3.1.3			Track Connectors
	1.1.2							Chassis - Structure Subsystem
		1.1.2.1						Hull Structure
			1.1.2.1.1					BALLISTIC SHIELD, EXHAUST OUTLET
			1.1.2.1.2					BAR, BULKHEAD
			1.1.2.1.3					BAR, HATCH INTERFACE
			1.1.2.1.4					BAR, REAR ENGINE
			1.1.2.1.5					BAR, REAR ENGINE BULKHEAD
			1.1.2.1.6					BASE,TRANSMISSION MOUNT
			1.1.2.1.7					BATTERY BOX - FRONT - PANELS AND SUPPORTS
			1.1.2.1.8					BATTERY BOX - REAR - PANELS AND SUPPORTS
			1.1.2.1.9					BEAM, ENGINE SUPPORT
			1.1.2.1.10					BEAM, ENGINE

									SUPPORT
			1.1.2.1.11						BLOCK (OPPOSITE)
			1.1.2.1.12						BLOCK, FLOOR PLATE MOUNTING
			1.1.2.1.13						BLOCK, IDLER SUPPORT, LOWER
			1.1.2.1.14						BLOCK, IDLER SUPPORT, LOWER
			1.1.2.1.15						BLOCK, IDLER SUPPORT, REAR
			1.1.2.1.16						BLOCK, IDLER SUPPORT, REAR
			1.1.2.1.17						BLOCK,FILLER,FINAL DRIVE
			1.1.2.1.18						BLOCK,FILLER,FINAL DRIVE
			1.1.2.1.19						BRACKET, PANEL, ACCESS, ENGINE
			1.1.2.1.20						BRACKET, PANEL, ACCESS, ENGINE
			1.1.2.1.21						CHANNEL BULKHEAD, REAR ENGINE
			1.1.2.1.22						CHANNEL BULKHEAD, REAR ENGINE
			1.1.2.1.23						CHANNEL, BULKHEAD, REAR ENGINE
			1.1.2.1.24						CHANNEL, BULKHEAD, REAR ENGINE
			1.1.2.1.25						CHANNEL, REAR ENGINE BULKHEAD
			1.1.2.1.26						CORNER, HULL, LOWER LEFT
			1.1.2.1.27						CORNER, HULL, LOWER RIGHT
			1.1.2.1.28						COVER, FINAL DRIVE
			1.1.2.1.29						COVER, FINAL DRIVE
			1.1.2.1.30						COVER, FINAL DRIVE(OPPOSITE)
			1.1.2.1.31						ENGINE BULKHEAD INSTALLATION
			1.1.2.1.32						FLANGE, FINAL DRIVE
			1.1.2.1.33						FLANGE, FINAL DRIVE(OPPOSITE)
			1.1.2.1.34						GUSSET, BULKHEAD
			1.1.2.1.35						GUSSET, BULKHEAD
			1.1.2.1.36						GUSSET, LOWER, LEFT FINAL DRIVE
			1.1.2.1.37						METAL, SPECIAL SHAPED SECTION

			1.1.2.1.38						METAL, SPECIAL SHAPED SECTION
			1.1.2.1.39						PANEL, BULKHEAD
			1.1.2.1.40						PANEL, DRIVER'S COMPARTMENT
			1.1.2.1.41						PANEL, SIDE FRONT
			1.1.2.1.42						PANEL, SIDE REAR
			1.1.2.1.43						PANEL, SIDE TRANSITION
			1.1.2.1.44						PLATE, BOTTOM LEFT REAR
			1.1.2.1.45						PLATE, BOTTOM RIGHT REAR
			1.1.2.1.46						PLATE, BOTTOM RIGHT REAR
			1.1.2.1.47						PLATE, BULKHEAD, LOWER LEFT
			1.1.2.1.48						PLATE, BULKHEAD, LOWER RIGHT
			1.1.2.1.49						PLATE, BULKHEAD, UPPER LEFT
			1.1.2.1.50						PLATE, COVER BULKHEAD
			1.1.2.1.51						PLATE, DRIVER'S DECK, SEGMENT 1-20
			1.1.2.1.52						PLATE, FILLER, TRANSVERSE
			1.1.2.1.53						PLATE, FORWARD, SIDE, SLOPED, SEGMENT 1-20
			1.1.2.1.54						PLATE, FRONT EXHAUST PLENUM
			1.1.2.1.55						PLATE, HULL BOTTOM FORWARD
			1.1.2.1.56						PLATE, HULL, BOTTOM CENTER
			1.1.2.1.57						PLATE, HULL, BOTTOM REAR
			1.1.2.1.58						PLATE, HULL, LEFT, FINAL DRIVE
			1.1.2.1.59						PLATE, HULL, LOWER FRONT
			1.1.2.1.60						PLATE, HULL, LOWER, LEFT SIDE
			1.1.2.1.61						PLATE, HULL, LOWER, LEFT SIDE
			1.1.2.1.62						PLATE, HULL, LOWER, RIGHT SIDE
			1.1.2.1.63						PLATE, HULL, LOWER, RIGHT SIDE
			1.1.2.1.64						PLATE, LEFT SIDE SEGMENT 1-20
			1.1.2.1.65						PLATE, LEFT GUNPORT, SEGMENT 1-20

			1.1.2.1.66					PLATE, PLENUM CLOSURE, SEGMENT 1-20
			1.1.2.1.67					PLATE, REAR SEGMENT 1-20
			1.1.2.1.68					PLATE, REAR SHOULDER, SEGMENT 1-20
			1.1.2.1.69					PLATE, RIGHT GUNPORT, SEGMENT 1-20
			1.1.2.1.70					PLATE, RIGHT INTERMEDIATE
			1.1.2.1.71					PLATE, RIGHT SIDE SEGMENT 1-20
			1.1.2.1.72					PLATE, RIGHT SIDE SLOPED, SEGMENT 1-20
			1.1.2.1.73					PLATE, RIGHT, SEGMENT 1-20
			1.1.2.1.74					PLATE, RIGHT, SEGMENT 1-20
			1.1.2.1.75					PLATE, SIDE, SLOPED SEGMENT 1-20
			1.1.2.1.76					PLATE, SPONSON, LEFT
			1.1.2.1.77					PLATE, SPONSON, LEFT REAR
			1.1.2.1.78					PLATE, SPONSON, RIGHT
			1.1.2.1.79					PLATE, SPONSON, RIGHT REAR
			1.1.2.1.80					PLATE, SUPPORT, IDLER SPINDLE FLANGE, LEFT SIDE
			1.1.2.1.81					PLATE, SUPPORT, IDLER SPINDLE FLANGE, RIGHT SIDE
			1.1.2.1.82					PLATE, TOP SEGMENT 1-20
			1.1.2.1.83					PLATE, UPPER FILLER
			1.1.2.1.84					PLATE, UPPER, FRONT, SEGMENT 1-20
			1.1.2.1.85					PLATE, VERTICLE SIDE SEGMENT 1-20
			1.1.2.1.86					PLATE,SIDE SLOPED,REAR SEGMENT 1-20
			1.1.2.1.87					REAR BULKHEAD, REAR ENGINE
			1.1.2.1.88					SIDE ADJUST PLATE, EXHAUST PLENUM
			1.1.2.1.89					STIFFENER, BULKHEAD, REAR ENGINE
			1.1.2.1.90					STIFFENER, LOWER

								HULL
			1.1.2.1.91					STIFFENER, LOWER RIGHT
			1.1.2.1.92					STIFFENER, REAR HULL
			1.1.2.1.93					STIFFENER,BULKHEAD, REAR ENGINE
			1.1.2.1.94					STOP, PEDAL BULKHEAD
			1.1.2.1.95					STRUCTURE,LOWER, WELDED
			1.1.2.1.96					SUPPORT, BULKHEAD
			1.1.2.1.97					SUPPORT, FLOOR PLATE
			1.1.2.1.98					SUPPORT, SLIP RING ARM
			1.1.2.1.99					SUPPORT, SLIP RING ARM
		1.1.2.2						Hull Hatches
			1.1.2.2.1					Engine Hatch System
			1.1.2.2.2					Driver's Hatch System
			1.1.2.2.3					Commander's Hatch System
			1.1.2.2.4					Rear Hatch System
		1.1.2.3						Bolt-on Armor
			1.1.2.3.1					ARMOR PLATE, BACK-UP
			1.1.2.3.2					ARMOR PLATE, CENTER, OUTER
			1.1.2.3.3					ARMOR PLATE, CENTER, OUTER
			1.1.2.3.4					ARMOR PLATE, COAMING, ENGINE ACCESS DOOR
			1.1.2.3.5					ARMOR PLATE, COAMING, ENGINE ACCESS DOOR
			1.1.2.3.6					ARMOR PLATE, FRONT BACK-UP
			1.1.2.3.7					ARMOR PLATE, FRONT, LOWER GLACIS
			1.1.2.3.8					ARMOR PLATE, FRONT, OUTER
			1.1.2.3.9					ARMOR PLATE, FUEL TANK, RIGHT SIDE
			1.1.2.3.10					ARMOR PLATE, LEFT FRONT GLACIS
			1.1.2.3.11					ARMOR PLATE, LEFT SIDE, LOWER CENTER
			1.1.2.3.12					ARMOR PLATE, LEFT SIDE, UPPER CENTER
			1.1.2.3.13					ARMOR PLATE, LOWER FRONT

			1.1.2.3.14					ARMOR PLATE, MIDDLE FRONT GLACIS
			1.1.2.3.15					ARMOR PLATE, REAR, OUTER
			1.1.2.3.16					ARMOR PLATE, REAR, OUTER
			1.1.2.3.17					ARMOR PLATE, RIGHT SIDE REAR, UPPER CORNER
			1.1.2.3.18					ARMOR PLATE, RIGHT SIDE, CENTER
			1.1.2.3.19					ARMOR PLATE,CENTER BACK-UP
			1.1.2.3.20					ARMOR PLATE,FRONT,OUTER
			1.1.2.3.21					ARMOR PLATE,LEFT SIDE
			1.1.2.3.22					ARMOR PLATE,REAR BACK-UP
			1.1.2.3.23					ARMOR PLATE,RIGHT FRONT GLACIS
			1.1.2.3.24					BODY, STOWAGE BOX, LEFT
			1.1.2.3.25					BODY,STOWAGE BOX,RIGHT
			1.1.2.3.26					BOX VEHICULAR ACCESSORIES STOWAGE
			1.1.2.3.27					BOX,VEHICULAR ACCESSORY STOWAGE
			1.1.2.3.28					BRACKET, CLEVIS, TIE DOWN
			1.1.2.3.29					BRACKET, CLEVIS, TIE DOWN
			1.1.2.3.30					BRACKET, CLEVIS, TIE DOWN
			1.1.2.3.31					BRACKET, CLEVIS, TIE DOWN
			1.1.2.3.32					BRACKET, CLEVIS, TIE DOWN
			1.1.2.3.33					BRACKET, CLEVIS, TIE DOWN
			1.1.2.3.34					BRACKET, CLEVIS,TIE DOWN
			1.1.2.3.35					BRACKET, DOUBLE ANGLE, SHIELD
			1.1.2.3.36					BRACKET, HEAD, HAMMER, HAND,10 LB
			1.1.2.3.37					BRACKET, MATTOCK HANDLE
			1.1.2.3.38					BRACKET, PIONEER TOOL HANDLE

			1.1.2.3.39						BRACKET, SHIELD, LEFT
			1.1.2.3.40						BRACKET, SHIELD, RIGHT
			1.1.2.3.41						BRACKET, SHOVEL
			1.1.2.3.42						BRACKET,CLEVIS,TIE DOWN
			1.1.2.3.43						BRACKET,CLEVIS,TIE DOWN
			1.1.2.3.44						BUMPER
			1.1.2.3.45						BUMPER, RUBBER
			1.1.2.3.46						CABLE, FLEXIBLE, FOOTHOLD
			1.1.2.3.47						CABLE, FLEXIBLE, STEP
			1.1.2.3.48						CATCHER, WIRE
			1.1.2.3.49						COVER, ACCESS, FINAL DRIVE
			1.1.2.3.50						DEFLECTOR, TRACK, LEFT
			1.1.2.3.51						DEFLECTOR,TRACK,RIGHT
			1.1.2.3.52						DISK,ARMOR
			1.1.2.3.53						DOOR ASSY, STOWAGE
			1.1.2.3.54						DOOR ASSY, STOWAGE BOX, LEFT SIDE
			1.1.2.3.55						DOOR ASSY, STOWAGE BOX, LEFT SIDE
			1.1.2.3.56						DOOR,STOWAGE BOX,RIGHT
			1.1.2.3.57						DRIVER'S HINGE COVER
			1.1.2.3.58						EPOXY, NON-SKID SILICON CARBIDE FILLED
			1.1.2.3.59						EPOXY, NON-SKID WITH SILICON CARBIDE PARTICLES
			1.1.2.3.60						EPOXY, NON-SKID WITH SILICON CARBIDE PARTICLES
			1.1.2.3.61						EPOXY,NON-SKID SILICON CARBIDE FILLED
			1.1.2.3.62						EPOXY,NON-SKID SILICON CARBIDE FILLED
			1.1.2.3.63						GUARD, STOWAGE, AXE
			1.1.2.3.64						HANDRAIL, METAL
			1.1.2.3.65						HOOK, TOW CABLE

								LEFT
			1.1.2.3.66					HOOK, TOW CABLE RIGHT
			1.1.2.3.67					HOOK,ELASTIC
			1.1.2.3.68					LOOP, STRAP FASTENER
			1.1.2.3.69					PLATE, ARMOR AND TOWEYE, FINAL DRIVE
			1.1.2.3.70					PLATE, ARMOR, BACK-UP
			1.1.2.3.71					PLATE, ARMOR, DRIVERS HATCH
			1.1.2.3.72					PLATE, ARMOR, RAMP DOOR
			1.1.2.3.73					PLATE, ARMOR, RAMP OUTER
			1.1.2.3.74					PLATE, ARMOR, REAR
			1.1.2.3.75					PLATE, RETAINER, TRIPOD, STOWAGE
			1.1.2.3.76					PLATE, SPACER, LEFT
			1.1.2.3.77					PLATE, SPACER, RIGHT
			1.1.2.3.78					PLATE, STRIKER
			1.1.2.3.79					PLATE, TAPPED
			1.1.2.3.80					SEGMENT, ARMOR
			1.1.2.3.81					SHIM, ARMOR PLATE
			1.1.2.3.82					SHIM, ARMOR SPACER
		1.1.2.4						Floor Plate
			1.1.2.4.1					Floor Plate
			1.1.2.4.2					Spall Liner
			1.1.2.4.3					Drain System
		1.1.2.5						Grills
			1.1.2.5.1					Exhaust Grill
			1.1.2.5.2					Intake Grill
	1.1.3							Chassis - Auxiliary Subsystems
		1.1.3.1						Electrical System
			1.3.1.1.1					Electrical Distribution
				1.3.1.1.1.1				Distribution Panels
				1.3.1.1.1.2				Wiring Harnesses
				1.3.1.1.1.3				Fusing
				1.3.1.1.1.4				Mountings/Fasteners
			1.3.1.1.2					Electrical Storage
				1.3.1.1.2.1				Battery Assemblies
					1.3.1.1.2.1.1			Battery Pack Forward

					1.3.1.1.2.1.2			Battery Pack Aft
				1.3.1.1.2.2				Battery fusing (28V)
				1.3.1.1.2.3				Battery Cabling
			1.3.1.1.3					Electrical Conversion
				1.3.1.1.3.1				DC-DC Converters
				1.3.1.1.3.2				Power Regulation
		1.1.3.2						Ventilation/NBC System
			1.1.3.2.1					Ventilation System
				1.1.3.2.1.1				Ventilation Fan
				1.1.3.2.1.2				Ventilation Filtration
				1.1.3.2.1.3				Ventilation Ducting
				1.1.3.2.1.4				Ventilation Mountings
				1.1.3.2.1.5				Ventilation Wiring
				1.1.3.2.1.6				Ventilation Sensing
				1.1.3.2.1.7				Ventilation Control
			1.1.3.2.2					Heating Systems
				1.1.3.2.2.1				Heater Assembly (~20kW)
				1.1.3.2.2.2				Heater Ducting
				1.1.3.2.2.3				Heater Mountings
				1.1.3.2.2.4				Heater Wiring
				1.1.3.2.2.5				Heater Sensing
				1.1.3.2.2.6				Heater Control
		1.1.3.3						Vetronics/C4
			1.1.3.3.1					Tactical Consoles
				1.1.3.3.1.1				Main Console
				1.1.3.3.1.2				Secondary Console
			1.1.3.3.2					Communications
				1.1.3.3.2.1				Tactical Radio Network
					1.1.3.3.2.1.1			Tactical Radio
					1.1.3.3.2.1.2			Tactical Radio Wiring
					1.1.3.3.2.1.3			Tactical Radio Antennas
					1.1.3.3.2.1.4			Tactical Radio Mountings
				1.1.3.3.2.2				Vehicle Intercom
			1.1.3.3.3					Vehicle Sensing
				1.1.3.3.3.1				Vehicle IMU
				1.1.3.3.3.2				Vehicle Inclinometers
				1.1.3.3.3.3				Vehicle GPS
			1.1.3.3.4					Vetronics Wiring
				1.1.3.3.4.1				Network Cable Assemblies

				1.1.3.3.4.2				Network Cable Mountings
		1.1.3.4						Crew Accomodation/Seating
			1.1.3.4.1					Seating
				1.1.3.4.1.1				Driver Seating
				1.1.3.4.1.2				Commander Seating
				1.1.3.4.1.3				Occupant Seating
		1.1.3.5						Fire Suppression
			1.1.3.5.1					Fire Suppression Control
				1.1.3.5.1.1				Control Panel
				1.1.3.5.1.2				Suppression Wiring
				1.1.3.5.1.3				Suppression Sensing
			1.1.3.5.2					Fire Suppression Distribution
				1.1.3.5.2.1				Fire Suppression Extinguishers
				1.1.3.5.2.2				Fire Suppression Plumbing
				1.1.3.5.2.3				Engine Specific Systems
			1.1.3.5.3					Fire Suppression Mountings
	1.1.4							30mm Remote Weapon System
		1.1.4.1						RWS Control System
			1.1.4.1.1					Console
			1.1.4.1.2					Console Vetronics Integration
			1.1.4.1.3					Console Electrical Integration
		1.1.4.2						RWS Turret
			1.1.4.2.1					Turret Structure
				1.1.4.2.1.1				Turret Frame
				1.1.4.2.1.2				Turret Payload Mountings
			1.1.4.2.2					Turrent Mounting
				1.1.4.2.2.1				Electric Turret Ring
				1.1.4.2.2.2				Electric Turret Ring Wiring
			1.1.4.2.3					Mk44 Weapon System
				1.1.4.2.3.1				Mk44 Weapon
				1.1.4.2.3.2				Mk44 Housing
				1.1.4.2.3.3				Mk44 Control
				1.1.4.2.3.4				Mk44 Wiring
				1.1.4.2.3.5				Mk44 Ammunition System
			1.1.4.2.4					Coaxial 7.62mm Weapon

				1.1.4.2.4.1				7.62mm Weapon
				1.1.4.2.4.2				7.62 Housing
				1.1.4.2.4.3				7.62mm Control
				1.1.4.2.4.4				7.62mm Wiring
				1.1.4.2.4.5				7.62mm Ammunition System
			1.1.4.2.5					AT Missile System
				1.1.4.2.5.1				AT Missiles
				1.1.4.2.5.2				AT Missile Housing
				1.1.4.2.5.3				AT Missile Control
				1.1.4.2.5.4				AT Missile Wiring
			1.1.4.2.6					RWS Sensing
				1.1.4.2.6.1				Day CCD Camera
				1.1.4.2.6.2				Cooled FLIR Camera
				1.1.4.2.6.3				Sensing Stabilization System
				1.1.4.2.6.4				Sensor Housing
				1.1.4.2.6.5				Sensor Wiring