Introduction

RNET Technologies Inc. (RNET) was founded in June 2003 with the goal of developing leading edge software, hardware and electronic systems that meet the needs of the DoD, DoE, NASA, Prime Contractors and other commercial companies across the U.S. Our core expertise is related to the design and development of "systems" with a focus on High Performance Computing optimizations and usability, combined with hardware (both board-level and chip-level), and firmware. RNET has developed numerous software and hardware components that have resulted in improvements to government owned systems, with some notable examples being optimizations to the Air Force CREATE-AV KESTREL code, the integration of GPGPU optimizations into PETSc development branch, and the development of Wattprof; a fine grained power monitoring board for emerging HPC systems. RNET, located in Dayton Ohio, was founded by Dr. V Nagarajan, an Ohio State University graduate with over 30 years of experience managing programs for various government customers (e.g., Air Force, Navy, Army, DARPA, NIST, DOE) and industrial clients. RNET has 6 employees and anticipates revenue of $TODO in 2019.

In 2018, RNET received a DOE Phase I contract to develop a software framework that facilitates end-user verification and validation in general purpose numerical simulation packages. To accomplish this objective, RNET has developed a prototype Verification and Validation (V&V) toolkit with three key features; (1) cross library support for inserting self describing testing points into existing applications, (2) runtime test injection that allows tests to be added or removed without recompiling the code, and (3) automated documentation generation that compiles test results into a responsive, publishable html/java-scrict reports. The prototype has been tested in several of RNETs internal codes, and in the MOOSE finite element code to good effect.

RNET is pursuing a DOE SBIR Phase II contract to optimize, harden and extend the framework into a fully featured V&V toolkit that can be used reliably across a range of high performance applications. The key research objectives of the Phase II proposal will be (1) the development of efficient statistical based V&V tools that can be applied in distributed settings; (2) hardening of the injection point delivery system to ensure the code is type-safe and maintains constant correctness; (3) implementation of a workflow management system for concurrency through job based parallelism; and (4) demonstration of the toolkit in real, production quality numerical simulations. Full realization of these objectives will result in a production ready V&V toolkit that can be demonstrated and sold to customers across the numerical modeling market.

To obtain the requested SBIR Phase II grant we are submitting this commercialization plan that highlights the commercial potential of our innovation as evidenced by: (1) the significance of the technical and or economic benefits of the Phase II research, (2) the likelihood that the proposed research will lead to a marketable product and (3) the likelihood that proposed research can attract further development funding. We have given this requirement considerable thought. We have examined markets and applications, talked to potential customers and partners, and assessed the resources necessary to realize the commercial potential of the innovation. As a result of this work, we find that our proposed SBIR/STTR innovation has a high commercial potential because:

- We have a good market opportunity.
- We have a company and team that is able to realize the value of this market opportunity.
- We can establish and sustain a competitive advantage.
- We can independently finance the anticipated commercial growth.

1 Market Opportunity

The strong market opportunity is the foundation of the V&V toolkit commercialization potential. Numerical modeling and simulation (M&S) is extensively used in numerous scientific and engineering fields and disciplines such as computational fluid dynamics, high energy physics, nuclear engineering, and computational finance. Software verification and validation, the process of determining that a simulation is fit for its defined purpose, prevents erroneous simulation errors from propagating into final designs and is a fundamental, unavoidable step in the technology transfer process for numerical simulations. It is this fundamental importance that motivates our assertion of a good market opportunity for the proposed V&V toolkit.

The V&V toolkit capitalizes on a growing need for tools that facilitate the V&V of simulations designed by the end-users of highly configurable numerical simulation packages. End-user V&V is extremely important because the ultimate costs of a design failure (e.g., financial, injury, or loss of life) lies with the simulation software user; any attempt to shift the blame to the software developers of simulation library X (including the V&V toolkit) will certainly fall on deaf ears.

However, while most high quality simulation packages have robust **internal** V&V regimens, few (if any) ship with a functionality that streamlines **end-user** V&V. Instead, software simulation developers often take a legal approach, whereby the licences include language to the effect of "*use at your own risk"* or "*this software is released as-is, with no guarantee it is fit for the intended purpose"*. The V&V toolkit tool addresses the need for simple end-user validation in numerical simulation codes by providing a unified framework that facilitates the development of *explainable numerical simulations*. These explainable simulations provide the end user with not only the result, but also a detailed report on how the solution was obtained and the reasons it should be trusted. This detailed report does not shift the burden of end-user V&V to the developer, that is, and always will be the responsibility of the end-user; rather, the framework provides a mechanism for providing the end-user with a level of knowledge about the inner workings of the simulation far beyond what is provided in most numerical simulation tools.

As we will show, the V&V toolkit has a good market opportunity because:

- It addresses an important, widely prevalent problem.
- It is a good solution to the problem.
- We can immediately address several problem instances.
- We have a sound plan for addressing these instances and have made good progress on this plan.
- There are other applications of economic, social, and scientific value.

1.1 Market Problem Addressed

End-user V&V for numerical simulations solves an important problem and serves as the basis for the good market opportunity because

- ***End-User V&V is essential***: Undetected errors in numerical simulations propagate into physical designs creating issues that can cost millions of dollars to fix, cause catastrophic damage to the environment, and, in the worst case scenarios, result in the loss of human life. The Sleipner platform accident[1] is a prime example of the potential problem, an offshore platform collapsed due to failures in the finite element simulation with devastating consequences (and $700M in damage). The Sleipner accident demonstrates

[1] The Sleipner Platform Accident, by B. Jakobsen and F. Rosendahl, Structural Engineering International 4(3), August 1994, pp. 190-193.
The Failure of an Offshore Platform, by R. G. Selby, F. J. Vecchio, and M. P. Collins, Concrete International 19(8), August 1997, pp. 28-35.

how a poorly verified numerical simulations can significant consequences on business, the environment, and society. The V&V library will greatly increase the quality of end-user V&V.

- **End-User V&V is expensive to set-up:** Verification and validation of numerical simulation is a notoriously difficult task that requires a broad knowledge of the algorithms and assumptions used in the development of the simulation. Acquiring the required expertise to implement such a plan is hard enough for the developers of the simulation; let alone for customers in industry whose entire reason for using the simulation package was likely to avoid spending the millions of dollars required to develop similar functionality internally. Integration of V&V reporting tools into the software libraries will greatly reduce the burden on the end user.
- **End-User V&V requires hundreds of man-hours:** Verification and validation is an iterative process that must be re-done each time any integrated software package is updated. Software development is itself an inherently iterative process, with 3-12 monthly release schedules being common among cutting edge numerical simulation packages. As such, keeping V&V reporting up to date is in itself an expensive, time consuming task. Automation of the reporting would significantly improve the results and reduce the costs.
- **Supporting End-User V&V is difficult:** For developers, integrating support for end-user verification is also an expensive, time consuming task. The primary reason for this is that most modern software packages utilize a deep hierarchy of third party numerical simulation packages. By allowing the developer to focus on their area of expertise, these third party packages dramatically reduce the time to market. However, robust end-user V&V requires through testing at every level of the simulation hierarchy, and as such, requires the developer to fully understand and modify the third party simulations. Such requirements counteract the primary benefit of using the third party libraries, knowledge compartmentalization, and as such, make supporting end-user V&V an unenviable task.

1.2 Targeted Market Solution

The concept of an integratable V&V toolkit it is a good solution to the problem of end-user V&V in numerical simulation packages, strengthening the market opportunity.

The V&V toolkit is a C/C++ framework that promotes the development of *explainable numerical simulations.* These are numerical simulations that not only provide the user with the solution, but also a detailed report as to how the solution was obtained and why the solution can be trusted. The toolkit will include a set of highly customizable, extensible and reusable V&V tests that can be configured by the end-user at runtime to setup a robust end-user V&V regimen. All V&V testing will be self documenting, streamlining the process of re-verifying a numerical simulation each time the numerical simulation package is updated. Moreover, the V&V documentation from a simulation will be presented as a modern HTML webpage that can be viewed in any web browser and/or hosted privately (with little to no cost) on services like AWS.

The functionality imparted by the V&V toolkit will be of exceptional value to the developers of numerical simulations in the areas of finite element analysis and computational fluid dynamics. The users of the toolkit will be those developers and their customers.

The developers of a numerical simulation will use the V&V toolkit to add robust support for V&V testing at critical points in the simulation. That functionality will then be used by the simulation library to verify and validate their own simulations. The V&V toolkit could also be used as a mechanism for verifying and validating the developers own code, both as a mechanism for functional in-situ testing and as a method for generating and performing V&V for any benchmark tests that are run.

To reiterate, the V&V toolkit is a good solution to the problems described above because it provides:

- **Explainable Numerical Simulations Increase Trust in the Solution**: The V&V Toolkit provides developers with the functionality required to build explainable numerical simulations. This addresses the need for end-user verification and validation in simulation packages by allowing for the development of simulations

that not only produce a result, but also a description of how the solution was obtained and why it can be trusted.

- **Runtime Configuration of Tests Reduces Setup Time**: The end-user V&V functionality facilitated by the toolkit is configurable at runtime through a single input file. This allows the users of the code to iteratively build a robust V&V regimen without ever touching the source code of the simulation.
- **A Robust Collection of V&V Tools Improves Efficiency**: The framework includes a robust collection of general-purpose V&V tools and statistical assertions optimized for performance in a large scale distributed settings. This significantly reduces the costs associated with completing end-user verification by removing the need to reimplement common algorithms for each simulation.
- **Automated Documentation Generation Reduces Time to Market**: The defining feature of the V&V toolkit is its support for automated V&V report generation. By providing the user with automatically generated, production grade V&V reports the framework reduces the burden of meeting the V&V reporting requirements.
- **Cross-library support simplifies integration**: The framework provides integrated support for multilingual, cross library V&V testing. This provides developers with a simple mechanism for facilitating end-user V&V at all levels of the simulation hierarchy. Such functionality will increase the appeal of the simulation package in the competitive numerical simulation market.

1.3 Wide Problem Prevalence

In addition to a good solution to the problem, we have a good market opportunity because the problem being addressed is widely prevalent. As mentioned above, computational simulations are a key component of the R&D pipeline in a range of industries such as computational fluid dynamics, high energy physics, nuclear engineering, and computational finance. The prevalence of smaller scale finite element analysis (FEA) software is even wider, with applications ranging from design optimization in $10 polycarbonate trinkets up to large scale parameter optimization of fighter jet wings. In all cases, the software used to inform the designs of these products must be verified and validated; and in all cases, the verification and validation of this software is a complex, time consuming task requiring input from experts across the broad spectrum of numerical simulation specialty areas (i.e., linear solvers, nonlinear solvers, finite element methods, physical domain specification, data analysis, etc.).

The primary market for the V&V toolkit is Computer Aided Engineering (CAE). Analysts at Grandview Research valued the CAE market at $6.65B in 2018[2]. Those same analysts predice the global CAE market will reach $12.8B by 2025, with a CAGR of 9.8% during the forecast period. Figure 2 shows the expected growth rates for the four main types of CAE; finite element analysis, computational fluid dynamics, optimization and simulation and multibody dynamics. The V&V

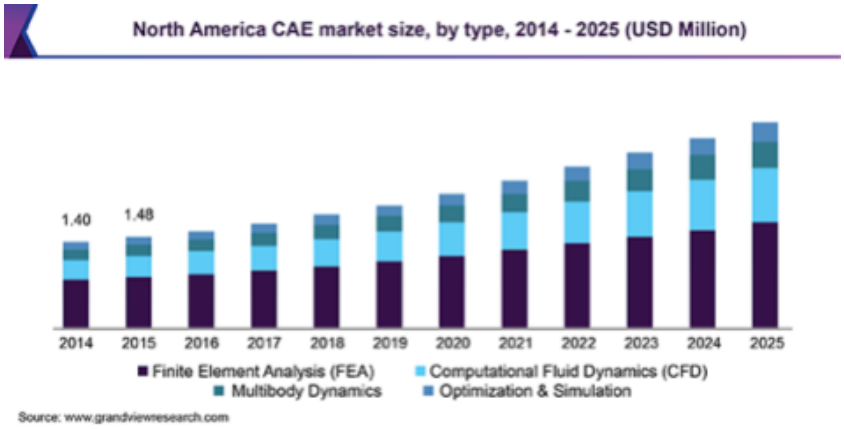

Figure 2: North America CAE market size for 2014-2025, Courtesy of www.grandviewresearch.com

[2] Computer Aided Engineering (CAE) Market Size, Share & Trends Analysis Report By Type (FEA, CFD, Multibody Dynamics, Optimization & Simulation), By Deployment Model, By End Use, And Segment Forecasts, 2019 - 2025,

Grandview Research, 2019, Report ID 1-68038-802-2

toolkit supports products in all sectors of this market.

1.4 Immediately Addressable Instances

In addition to wide problem prevalence, we have a good market opportunity because we can solve important problem instances upon product release (i.e., near the end of the Phase II contract):

- **The NEAMS toolkit** The initial targeted instance will be the NEAMS (Nuclear Energy Advanced Modeling and Simulation) toolkit that is developed by the Department of Energy's (DOE) Office of Nuclear Engineering (NE) . The NEAMS toolkit will provide "pellet-to-plant" simulation capability with an unprecedented degree of predictability for a broad class of advanced reactor and fuel cycle systems by leveraging leading edge computational methods and high performance computing technologies. The NEAMS toolkit provides a comprehensive advanced reactor simulation suite that is state-of-the-art in the nuclear reactor design community. The contentious nature of nuclear energy research led to an in depth specification for software verification, validation and design accreditation in the industry. Despite implementing a robust V&V plan, the NEAMS tools still suffers from the issues associated with end-user V&V (as evidenced via repeated calls for "automated solutions for end-user numerical simulation verification" in DOE SBIR solicitations (2018.2, 2019.2, etc) and through discussions NE program managers).
- **OpenFoam:** OpenFOAM is an open source CFD package developed primarily by OpenFoam Inc. It is independently tested by ESI-OpenCFD's Application Specialists, Development Partners and selected customers, and supported by ESI's worldwide infrastructure, values and commitment. OpenFoam represents a well used, well supported open-source package that RNET can use to demonstrate the exceptional value of the V&V toolkits explainable numerical simulation tools.

By addressing these specific instances, RNET will be able to prove to potential customers that the V&V toolkit is a robust, feature packed toolkit that can be efficiently integrated into a production grade product as a means for providing self verifying, self explaining simulation tools to their end-users.

1.5 Market Entry Plan: Direct Integration into Existing Simulations

A sound plan for addressing the targeted addressable instances further improve the market opportunity. The plan includes 4 stages; with the initial market entry stage described here. The entry plan for the V&V toolkit will be to establish two to three integration contracts, whereby RNET directly integrates the toolkit into the customers existing numerical simulation tools.

These reference accounts will be used to establish sustainable positive cash flow while also allowing RNET to fully battletest the framework in real world applications. In addition, these reference accounts are important because they foster a level of trust in the toolkit and, most importantly, provide proof that the solution is not simply "vaporware" and can be used reliably in production environments.

RNET will seek out these contracts by presenting at industry specific conferences and workshops. These meetings provide a convenient vehicle to market to developers, decision makers, and stakeholders of advanced numerical simulation tools. In each case, the NEAMS support for end-user V&V will be used to demonstrate the tremendous value of the toolkit. RNET has attended these meetings in the past, and will utilize these opportunities towards the end of the Phase II project.

This is a sound entry plan because it allows RNET to establish sustainable positive cash flow while also allocating time to cement our position as the leading supplier of end-user V&V functionality and provides a mechanism for addressing the bugs and issues that are inevitably associated with early adoption.

1.6 Subsequently Addressable Market Opportunities

In addition to a sound and realistic plan for addressing initial problem instances during market entry, additional (progressively larger) markets opportunities will be addressed once we have secured our initial market position.

These additional addressable markets ensure that the market opportunity is sufficient to sustain the product and company. After the initial market entry (stage I), three additional stages will be addressed (commercial V&V toolkit sales, dual licensing (open source and commercial) and integration into a wide range of software libraries, and extension of the V&V toolkit into other areas such as parallel debugging and profiling). These market opportunities include:

- **Commercial Sales Toolkit and Support Services**: Once the value of the toolkit has been proven, RNET will make the V&V toolkit available to select companies and research organizations through support and training contracts. The primary benefit of this approach is that the exposure to different code bases will provide a mechanism for weeding out unforeseen bugs prior to the wide scale release of the software. The V&V toolkit has application in scientific and engineering fields and disciplines such as computational fluid dynamics, high energy physics, nuclear engineering, and computational finance. Additionally, based on feedback from customers, this stage will allow us to refine the user-experience of the toolkit. At the completion of this stage, we will have a well tested, well documented software package that has been thoroughly tested using multiple code bases and attack angles. Wide scale marketing of the toolkit through attending and presenting technical conferences, attending academic meetings and submitting journal publications will be complete during this phase of the commercialization plan.
- **Open Source and Commercial Licensing**: The core functionality of the V&V toolkit will be released under both a commercial license and an open-source source license (e.g., GPL). This will allow the software to be integrated into other Open Source projects, while requiring a license for commercial integration and distribution. The open source license will allow users to freely use the V&V toolkit in private and academic codes, helping adoption of the V&V toolkit and allowing users the ability to learn the value of the product (support contracts will also be available). A one time commercial license fee will be required to integrate the V&V toolkit into commercial software, and recurring user license fees will be charged for each end-user of the third party software that includes V&V toolkit features. The one time licensing fee will include integration support. Releasing the core functionality of the software open-source is expected to drive the uptake of RNETs support services. The specific benefits of this open-source model are that: (1) it fosters a community of developers and users that, in turn, provide free marketing for the product (2) it acts as a mechanism for allowing testing of package prior to purchasing a support contract, and (3) it allows for quick proliferation of the toolkit into a wide range of academic codes, creating a wide user-base that will lead to a demand for V&V tools in more commercial codes.
- **Expansion into Parallel Debugging and Profiling**: Issues associated with debugging and optimizing large-scale numerical simulation have long been an issue in the high performance computing community. To that end, there are a huge number of HPC debuggers and profiling libraries (e.g., TotalView, Tau, Vampir, HPCToolkit, etc.). In terms of optimization, the V&V toolkit provides a highly configurable, intuitive mechanism for inserting profiling code directly into an executable. In addition to providing an efficient mechanism for the tried and true method of debugging - the printf statement - the robust set of statistical tools provide an effective means of asserting the state of variables distributed across hundreds of thousands of cores. In fact, the statistical methods to be developed in Phase II were first developed as a mechanism for distributed relational debugging. In many respects, parallel debugging can be thought of as a less-formal, human in the loop version of V&V. Further research into runtime streaming of V&V test results, after success in the V&V market, will lead to a natural transition to, and penetration of the parallel debugging market.

1.7 Broader Social and Economics Benefits

The confidence instilled by an automatic toolkit generated V&V regimen will act as a bridge between the cutting-edge simulation technology and systems level engineers in industry, thereby increasing the rate of technology transfer for commercial, government, and academic based R&D codes. The integration of cutting edge simulation tools in the deering into the systems engineers design pipeline will lead to improved designs,

faster time to market and improved safety, while also ensuring the public benefits from the nations significant investment in advanced simulation capabilities.

2 Company/Team

In addition to a good market opportunity, we can achieve the required level of commercial success because we have the company resources and team able to realize the value of the market opportunity. RNET Technologies (RNET), located in Dayton, Ohio, was founded in June 2003 as a "C" Corporation organized under the laws of the State of Delaware. RNET is a C-Corp with a personnel structure that consists of the President at the top, and project managers and engineers at lower levels. The overall mission of RNET is to develop leading-edge (embedded, system, and application) software, hardware, and electronic systems that meet the needs of the DoD, DoE, NASA, Prime Contractors and other commercial companies across the U.S., as well as the private, domestic, and international sector. Our core expertise is related to the design and development of "systems" with a focus on High Performance Computing optimizations and usability. The high-level mission of RNET is to develop commercial products that are initially based on government funded research, but can be grown into significant products used by government and private entities.

Over the years our founders have created a company and team able to realize the full value of our market opportunity of our SBIR/STTR innovation because:

- We have a good company foundation
- We have the right team
- We have already made good progress toward the V&V toolkit

2.1 Good Company Foundation

As mentioned, one reason we can realize the full value of our market opportunity, is because RNET has a good company foundation.

Kestrel and PETSc optimizations are two examples of integration of RNET optimizations into government owned codes. We have made optimizations to Kestrel, an Air Force CFD and CSD simulation code. These optimizations included the Kestrel CFD solver, CSD solver, and fluid structure interaction for modern HPC architectures. These optimizations were shared with the Kestrel team and integrated into Kestrel. RNET had also collaborated with the Ohio State University and Argonne National Laboratory to develop PETSc extensions targeting petascale architectures, and these extensions were included in the PETSc development branch.

Some of the hardware systems we have designed and built include the "user-programmable" 10 Gigabit Ethernet NIC (network interface card) named "SmartNIC" along with several modules of application-level and network-level offload engines for HPC applications. Part of the development of the "OCTEON Plus" NPU-based 10 GigE SmartNIC was funded by DOE SBIR/STTR projects. In addition, RNET has invested an additional $60K and built about 25 SmartNICs. We have also made an additional investment of about $70K for designing and building 10 OCTEON-II based next generation SmartNICs, to be marketed to HPC users.

We have also developed a "fine-grained" Power Monitoring system (called WattProf) consisting of a custom-designed FPGA board containing various analog to digital converters, memory and storage, along with the required firmware and data-acquisition software for HPC applications. WattProf will be useful both for large government owned HPC centers and private data centers. Initial WattProf commercialization included a $100k contract to extend WattProf to integration with Sandia National Laboratory libraries.

As part of another DOE project RNET developed the HD TomoGPR, a novel below ground imagining system for fine root analysis using tomography and Ground Penetrating Radar. RNET is currently organizing the sale of the initial prototype with PNNL. Finally, as part of another DOE project, we developed optimizations to BigData platforms (iNFORMER). Sales opportunities for iNFORMER are being explored with major Big Data players

including Lexis Nexis and Hortonworks. We have recently been awarded the Yarn Ready certification for a Map Reduce like API and are pursuing market release strategies with Hortonworks.

Revenue Type	2016	2017	2018	2019
Product Sales	$100,000			
Consulting Services		$50,000		
SBIR Grants	$1,953,176	$1,113,170	$1,250,000	TODO
Contract R&D			$150,000	

2.2 Right Team

In addition to a good company foundation, we can realize the value of our market opportunity because we have the right commercialization team. Currently RNET has six full-time employees, all with graduate degrees and two with industrial experience. Of these, four full-time employees have Ph.D. degrees. The remaining employees have Masters degrees. RNET employees are some of the best in their area of expertise, and have first-hand experience with the state of the art technologies. As a team, the employees at RNET are capable of designing innovative high-tech software products that serve national interests in their matching areas of expertise.

Dr. V. Nagarajan is the President of RNET and will supervise the commercialization operation. He has a Ph.D. in Operations Research and Computer Science and an M.B.A. from the Ohio State University. He has over 30 years of research experience, managing programs for various government customers (e.g., Air Force, Navy, Army, DARPA, NIST, DOE) and industrial clients. As the official responsible for business development, he will work on the overall strategy for successful commercialization of the V&V toolkit. Currently, Dr. Nagarajan is developing strategies for collaborating with universities and national laboratories to develop and commercialize R&D ideas, and industries to develop product marketing plans. He is also interacting with potential investors to raise funding for product commercialization.

Dr. Ben O'Neill will be the PI for the project. He has a Ph.D. in Applied Mathematics (with a focus on distributed HPC computing and parallel time integration) from the University of Colorado at Boulder. Dr. O'Neill will act as the technical lead for the project. From a commercialization standpoint, his role in the project will be to facilitate communication between the end-users of the code and the development team to ensure that the V&V toolkit meets the needs of the community.

Dr. Gregory Watson (Research scientist, ORNL) has been brought in as a collaborator. Dr. Watson is the primary developer of the Eclipse Parallel tools platform, a software package that has seen wide scale uptake in applications across academia and industry. His contacts and experience gained developing and driving uptake of this platform will be extremely important.

RNET also has a working relationship with TideMark Group Limited in Columbus, Ohio. TideMark Group identifies market opportunities; locates, qualifies, and develops relationships with suppliers and/or business partners; develops strategic plans for the export, import, or capitalization of trade opportunities in identified markets; and then implements these plans. RNET has worked with TideMark in the past, and will pursue a similar relationship for the V&V toolkit if needed.

2.3 Good Progress: V&V Toolkit

Finally, we can realize the value of our market opportunity because we have already made good commercial progress. This statement is largey backed by the successful development of a functioning proof of concept during the Phase I award period. The key milestones achieved so far:

- **Jul 2018**: Obtained SBIR Phase I funding for the V&V toolkit.
- **Dec 2018:** Version 0.1 of the V&V toolkit is completed.
- **Feb 2019**: The V&V toolkit is successfully tested in simple finite element applications.
- **April 2019**: Set up collaboration agreement with ORNL for the research, development and testing in the Phase II project.

2.4 Intellectual Property/Competition

In addition to the right company resources and people, we can achieve the required level of commercial success because we can establish and sustain a competitive advantage.

While there do exist several software packages with integrated V&V procedures, there does not yet exist a generic, cross library toolkit that provides anywhere near the full array of functionality required by end users and provided by the V&V toolkit. In vendor tools (e.g., ANSYS, Altair, Fusion360, etc.), verification and validation of the overall package is par for the coarse, however, support for end-user verification techniques such as mesh refinement studies or the method of manufactured solutions is limited. When these tools do exist, they are application specific and cannot be applied across libraries. Many open-source tools have integrated V&V procedures; but again, these tools are application specific and are not implemented consistently across all levels of the applications software hierarchy. Therefore, these tools do not meet the industry wide V&V requirements.

The runtime specification of generic V&V tests, combined with automated post processing of the results is a defining and novel functionality of the V&V toolkit and has no clear open source or commercial competitors. These product capabilities enable us to establish and sustain competitive advantage because:

- We offer extraordinary value.
- We have protected our intellectual property.
- We have superior technology.
- We can manage competitive rivalry.

2.5 Extraordinary Value Proposition

We can establish a competitive advantage partly because we offer customers extraordinary value. Simply put, numerical software should not, under any circumstances, be used to inform real world design decisions without a robust simulation verification and validation plan. To that end, the proposed V&V toolkit provides customers with extraordinary value because :

- **It Reduces Time To Market**: The V&V toolkit is a huge value add from the perspective of developmental efficiency, a fact that will inevitably reduce the time to market for simulations that use the toolkit. Integration of the V&V tools into simulation code allows it to be used as part of the standard benchmark testing suite. As such, it provides a robust, self documenting approach to generating benchmark based V&V testing reports that are automatically updated each time the software changes.
- **Increases Appeal in a Competitive Market**: The web-based format of the V&V test results provides a modern, highly informative V&V report that instills a level of trust in the solution that is not available using standard approaches. This will increase the appeal of the simulation package in a very competitive market.
- **It Reduces Support and Training Requests**: The explainable numerical simulations produced by V&V equipped simulation packages provide a detailed report regarding every aspect of the simulation process; from what algorithms were used, through to a sensitivity analysis. Through this report, users will be able to immediately detect and fix any issues in the configuration. In turn, this will significantly reduce the number of support inquiries relayed back to the simulation software developer.

2.6 Intellectual Property Protection

In addition to extraordinary value, we establish competitive advantage because we have sound intellectual property protection for our innovation. During the early stages of development, RNET will use trade secrets and non-disclosure agreements to protect its intellectual property. Once our position in the market has been cemented, RNET will pursue an open-source distribution model where by the core functionality is made freely available. Releasing the core components as open-source is a large, but necessary intellectual property risk designed to capitalize on the goodwill and market penetration that can be gained through open source distribution in academic and governmental settings. Integration of the V&V toolkit into a huge range of smaller academic R&D codes is expected to drive interest and demand for RNET's V&V integration services and licenses in well funded commercial simulation projects.

This is a sound, effective and realistic plan because it balances the needs for IP protection with the market's desire for open source software. In particular, it provides us with enough time and IP protection to build a collection of reference accounts that demonstrate the exceptional value of the V&V toolkit and the support of integration services provided by RNET.

2.7 Manageable Technological Threats

We see no unmanageable threats to the superiority of our technology. This, in addition to sound intellectual property protection, will allow RNET to establish a clear competitive advantage.

As stated above, the uniqueness of the V&V toolkit lies in its uniform, cross library, and cross language API for developing self describing, explainable numerical simulations with built-in and highly configurable mechanisms for V&V. We currently see no alternative product, technology, or innovation able to achieve higher performance or effectiveness. However, the following commercial tools and academic research are being viewed as competitors, although none exactly match in application support, function, and usability.

- **National Instruments (NI) TestStand**: The NI TestStand software provides a modular architecture with well defined components to address the various needs of a software testing system. The modularity of the testing components aids in V&V efforts by allowing the customer to define the specific components needed in each simulation and allows each component to be analyzed independently. TestStand process models handle test functionality that is not specific to a unit under test, including UUT tracking, report generation, database logging, and batch/parallel testing. The process models that ship with TestStand are complex, so making changes to these models requires a significant validation effort. TestStand is an impressive, commercially supported testing framework and interface with a good industry reputation; however, testStand is primarily targeted toward software developers with no emphasis on numerical simulation end users, and as such does not pose a significant threat to the V&V toolkit. In particular, TestStand provides no specific focus on the needs of the numerical simulation community, and, in many ways, represents the exact problems with applying software development testing frameworks in a numerical simulation setting that the V&V toolkit is addressing.
- **SimScale**: SimScale delivers a trusted computer aided engineering (CAE) platform. Through verification, SimScale ensures that the problem was conducted properly. Through validation, they take it to the next step to ensure that the results reflect reality. On a regular basis, multiple validations are performed, where obtained results are compared either to analytical or experimental data. SimScale offers computational fluid dynamics (CFD) validation, finite element analysis (FEA) validation, and thermal validation. SimScale is used by numerous Fortune 500 companies, and has reached over 50,000 users worldwide with estimated revenue of $6.5 million. However, the verification and validation tools available in SimScale are application specific and can only be used inside SimScale codes. Although we are not privy to SimScale source code, it would likely be a huge, if not impossible, task to extract that V&V functionality into a generic set of tools that would rival the functionality of the V&V toolkit. In fact, SimScale represents a software package that,

during early development, could have benefited from the automated V&V testing afforded by the toolkit. Moreover, we feel the explainable simulations capabilities achieved through integration of the V&V toolkit would provide tremendous value to the users of SimScale, even on top of the robust V&V plan already in place. Thus, RNET sees SimScale not only as a rival, in that they have the experience and expertise required to develop a product similar to the V&V toolkit, but also as a potential customer. A similar argument holds for other popular CFD and FEA frameworks such as Altair Hyperworks and ANSYS Fluent.

- **Numalis**: Numalis provides tools for validating and optimizing sensitive industrial programs headed for critical sections such as aeronautics, aerospace, and defense. Numalis offers a solution for V&V called Spoat. The current range of Spoat products is composed of Spoat-Vulnerability (automatic detection of numerical issues) and Spoat-Trust (builds a reliable benchmark for numerical functions). The goal of Spoat-Vulnerability is to find vulnerabilities on variables, blocks, functions, and modules of the code. Vulnerabilities can be a drift in the numerical accuracy, unstable code, or a risky cast. To do so, Spoat-Vulnerability relies on dynamic, static, and statistical analysis (if used alongside Spoat-Trust). This represents functionality that developers would be able to replicate using the V&V toolkit when defining a new V&V testing tool. We do not see Spoat as a technological threat to our competitive advantage because it lacks the core functionality of the V&V toolkit -- explainable, self documenting numerical simulations that can be tested and analyzed at runtime. Of all the competitors, Numalis is best positioned to develop a rival product, however we feel that our staged IP protection plan and releasing the core software open source will act to mitigate this risk.
- **Open Source C++ Unit Testing Frameworks**: Literally hundreds of C++ unit testing frameworks are a potential competitor to the V&V toolkit that are available (with Google-test being the most prominent). However, these unit testing frameworks are a competitor only in the sense that they provide a means for implementing V&V of software using an approach to software verification (unit testing) that is extremely popular across enterprise and academic software development. We expect the V&V toolkit to be used in conjunction with a standard unit testing framework and expect few technical challenges from such frameworks; however, it would be remiss to omit the current status-quo as a potential barrier to commercial success.

Competitor	Markets Served	V&V Toolkit Differentiator
NI TestStand	Software developers, web, ui, enterprise	● Built with numerical simulation in mind. ● Runtime configuration for in-situ V&V testing. ● Robust I/O for creating explainable simulations. ● Automated V&V report generation with built in support for 2D and 3d visualization.
SimScale (and various other CAD/CAE Vendors)	Computational fluid dynamics, finite element analysis, structural analysis	● Automatic report generation. ● No vendor lock in. ● Supports open source tools.
Numalis	Code validation and optimization in aerospace, aeronautics, defence, etc	● Runtime test specification and configuration. ● Generates a responsive, publication grade HTML V&V report ● Enables development of explainable Numerical simulations.
C++ Unit Testing Frameworks	Software development, numerical simulation	● Specifically designed to suit the needs of the numerical simulation community. ● Tests that can be configured at run-time and run in-situ without the need to recompile ● A simple markdown syntax for providing final V&V report content and formatting.

2.8 Manageable Non-Technical Threats

In addition to sustainable technological superiority, we can establish a competitive advantage because we can manage non-technological threats from rivals.

The primary non-technological threat is the recognized expertise of and prior purchase of rivals in the fields of software development. In this regard, RNET has identified Kitware, a U.S based company that substantial R&D with researchers and academics at government labs and universities as a key rival. Kitware have achieved widespread usage of their Cmake build system, and Paraview and VTK based software visualization tools. In fact, the Phase I prototype of the V&V toolkit integrates with the Kitware open source VTK.js framework for enabling 3D scientific visualization in web based V&V reports. Kitware also played a part in the development of ADIOS, the IO system used in the V&V toolkit for writing the data to file. Kitware does not currently have any V&V tooling; however, their expertise in efficient scientific visualization positions them as a company that could potentially develop a similar product. As with Numalis, this risk will be mitigated as best as possible by using the proposed staged IP plan. The elements of the V&V toolkit that use the Kitware tools, namely an extension to the markdown syntax for processing and presenting scientific data, will be released as part of the open-source toolkit components.

Another non-technical threat is the reluctance to becoming an early adopter of the V&V toolkit. The toolkit will reach its true potential when it has been integrated into tools spanning the numerical simulation hierarchy, from low level linear algebra packages like PETSc, up through advanced multiphysics packages like MOOSE. The proposed three stage V&V market entry plan is designed to mitigate this risk by allocating time and resources during the first two years of commercialization to building a diverse set of reference accounts that fully demonstrate the value of the toolkit. Thus, we see no unmanageable non-technological rival threats.

3 Finance and Revenue Model

In addition to a good market opportunity, the right company resources and team, and the ability to create and sustain a competitive advantage; we can achieve commercial success because we have a sound and realistic finance and revenue model.

The short term goals for the product are to generate sufficient revenue to cover the robust testing and integration required to demonstrate the value of the V&V toolkit and to allow for the development of advanced V&V features. Software V&V is a requirement that is not going away anytime soon; thus, achieving these goals will allow the V&V toolkit to claim the position as the de-facto standard for an integrated V&V testing environment. The CAE and simulation market supported by the V&V toolkit is estimated at $6.65B with a market growth rate of 9.8% year over year as described in Section 2.

To fund these goals, RNET will use a combination of support contracts, government contracts/grants, product licensing sales, and internal funding. The finance and revenue model that will be used to commercialize the V&V toolkit is sound and realistic because we have a soundly staged commercialization plan, have realistic cost estimates for each stage, can cover the cost of each stage, can provide a good return on Phase II investment, and can acquire additional funds as necessary.

3.1 Soundly Staged Plan

We have a sound and realistic finance and revenue model because we have a sound, four stage commercialization plan as outlined below.

- **Reputation Generation**: The first stage will begin during the final year of the Phase II award and will include procuring non-SBIR government grants/contracts for integration of the V&V toolkit into existing

government tools. As outlined in the market entry description, the goal of Stage I will be to generate sufficient contract based research funding to support robust testing and integration into real world codes. Extensive marketing efforts will also begin in Stage I. Historically, we have seen little benefit from advertising advanced technology such as this using standard paid advertising channels (magazines, internet advertisements, etc.). Rather, the toolkit will be advertised through direct communication with developers, scientific publications, and technical presentations and tutorials at conferences.

- **Integration and Support**: Stage II will focus on support and integration contracts for industrial and government users, and release the V&V toolkit as a stand-alone product for integration into simulations. The goal of this stage will be to generate revenue to cover the costs of the support services offered, to develop new tools and functionality, and to keep the code up to date with the latest advances in high performance computing.
- **Distribution**: At this point in the project, the V&V toolkit will be a robust, well tested framework that has been demonstrated to work in a number of academic and enterprise applications. Further research and development funded through revenue from Stage I and II will help cement the toolkit as best in class. In Stage III, RNET will release the core components of the toolkit to the general public as open-source software. An open-source distribution will ensure wide scale uptake across academia that will drive demand for the V&V toolkit functionality in large commercial applications. Revenue will be generated from the sale of support and training services. The ultimate goal for this stage is to get the V&V toolkit integrated into a commercial tool such as SimScale, Fusion 360, and/or Hyperworks.
- **Expansion**: The final stage is to modify the V&V toolkit to suit validation needs in other areas like AI and server side software development. A recharacterization of the toolkit as a full software testing framework, including integration of a unit testing framework and the development of automated testing functionality will be pursued during this expansion. Funding for these expansions will be provided by new and on-going integration contracts and through support contracts. A similar, staged commercialization plan (steps I-III) will be used for bringing the V&V tools developed in these new areas to market.

This plan is soundly staged because:

- **It promotes reliability**: Releasing an incomplete and poorly tested software package too early in the design pipeline results in a poor user reputation and can open the door for other companies to develop a competing, potentially better functioning product. It would be naive to assume that we can account for every use case and issue within the initial Phase II project, thus, the initial focus on support and integration contracts is appropriate because it provides a large (3 year) self-sustaining window of revenue generation where we can complete testing and develop unforeseen enhancements required to cement the toolkit as best in class, while also mitigating risks associated with the development of rival products.
- **It builds a solid reputation**: The largest barrier to market for any simulation technology is customer uptake. The proposed plan will slowly build a reputation as the best in class for the V&V toolkit by demonstrating the value of the product and our services in a growing set of reference accounts. These reference accounts will then be used to drive further sales of support and integration contracts.
- **It suits the market**: The open-source, contracts based model is a common approach to the commercialization of advanced technologies like numerical simulation software. The approach is successful because it balances the communities desire for free and open-source software, with the need to profit from the project. When done correctly, this approach fosters a community of end-users that are often willing to provide feedback, track bugs, and commit fixes. It is that user feedback that will keep the toolkit on the cutting edge and allow us to adapt to new and emerging architectures and challenges.

3.2 Realistic Cost Estimates

In addition to having a soundly-staged commercialization plan, we have a sound and realistic finance and revenue model because we have realistic estimates of the cost for each stage. The projected expenses for the

first five years of the project are outlined in the Pro-forma. RNET uses a OH rate of 54% for all employees and a G&A rate of 7%. These figures were obtained under the following assumptions:

- One technical sales and marketing employee will be hired in 2021 at a salary of $120K in accordance with similar positions in the Dayton area. RNET will allocate 50% of this employees time to the V&V toolkit sales and marketing, and 100% thereafter. One additional sales staff will be hired in 2023, again at a salary of $120K.
- One technical support person will be hired in 2020 with a 50% allocation to this project during 2020 and 100% thereafter. The base rate for a technical support member is estimated as $80K. An additional technical support allocated to the project in 2021.
- Research and development will be covered entirely through SBIR funding during the first two years. RNET will allocate 1, 1.5 and 1.875 research scientists to R&D in 2021,2022 and 2023, all at a base rate of $120K.
- RNET expects a facilities cost of approximately $10,000. Legal expenses are also needed to support our interactions with our legal counsel, partners and USPTO, including licensing and IP negotiations with our partners as well as patents and trademarks where necessary. The amount of legal services required will increase based on sales, and include initial effort for an extensive patent search and other initial legal expenses (EULA creation). RNET's G&A expenses are 7% of sales, R&D, facilities, and legal expenses.

These cost estimates are realistic cost estimates because they are largely focused toward growing and retaining a competent team capable of successfully commercializing the product, both from a technical and marketing/sales perspective.

3.3 Revenue Streams

The V&V toolkit includes five revenue streams; end user support contracts, commercial integration licenses, commercial user contracts, commercial integration contracts, and R&D contracts. All prices will be fully evaluated during Phase II and modified as appropriate.

- End user support contracts provide support (updates, 24 hour email support, bug fixes requests, etc.) to users of the V&V toolkit, including open source developers, commercial users using the V&V toolkit on internal products (i.e., not for sale or distribution), and users of open source products that leverage the V&V toolkit (e.g., NEAMS users who desire support). The current expected annual price is $5,000 per user. The price fits inline with others in the industry, including the NI TestStand which offers its product and full support package at $4500 per year.
- Commercial integration licenses allow the V&V toolkit to be integrated into commercial code and to be distributed in commercial products (as opposed to Open Sources licenses that require any changes or integrated products to be Open Sourced). This license includes a fixed number of user licenses and integration support. The current expected one time cost (per major product release) is $75,000.
- Commercial user licenses are a fixed cost (per user) royalty. A commercial V&V license is required for each licensee of client software that includes V&V toolkit features (e.g., ANSYS FLUENT users). It is possible that toolkit customers (e.g., ANSYS) will provide their users V&V features only in premium products, or as a separate add on license fee. It is expected that royalty licenses fees will be negotiated, initial fees are expected to be $1,500 per user. This is a reasonable cost as simulation software licenses can range from $1,000's to $100,000+ and V&V is a critical component for many users.
- RNET will perform integration of the V&V toolkit into commercial or government codes using integration contracts. The cost of these contracts will vary based on the application complexity. An initial estimate is $250,000 per integration contract. The price per contract was determined under the assumption that integration will take a research scientist 8 months and is inline with contracts RNET has received in the past.
- RNET will also perform feature updates and modifications to support new simulation methodologies and to develop/support new V&V techniques via R&D contracts. It is anticipated that these contracts would be sold to government agencies. An example of such a contract would be from a government agency to

develop a specific test library for a given application. The average price of $225,000 was used in accordance with other short-term government R&D contracts such as SBIR Phase I awards.

3.4 Covered Costs

The first five years of projected operating earnings covering the full three stage financial plan are summarized in Section 4 of the Pro-forma. These estimates are based on the following assumptions of revenue generation during each stage:

- **2019:** RNET will rely entirely on SBIR funding for 2019. After expenses and taxes, the V&V toolkit is expected to have an operating margin of 7% in 2019; all of which will be reinvested into R&D in 2020.
- **2020:** The first commercial sales are expected in 2020 in the form of a single integration contract. After expenses, RNET expects a $113k profit in 2020.
- **2021:** We project that we will obtain 1 additional integration contracts. We also expect to third party users 25 users (resulting from the first integration), and 10 V&V toolkit users support contracts. RNET also expects one commercial licence and one R&D contract for extending the toolkit. The operating margin for 2021 is expected to be 8.6%.
- **2022:** We will look to ramp up our integration efforts. We expect to have 200 third party (royalty) users and 50 V&V toolkit users. RNET will look to obtain two integration contracts, sell two commercial licences and acquire one R&D grant/contract. This marks the first point at which the V&V toolkit will make a profit, with an operating margin of 22%.
- **2023:** RNET projects it will sell two integration contracts, 1 R&D contract, and two commercial licenses in 2023. Additionally, we are projecting 1500 third party users and 150 V&V toolkit users. At this point the majority of the revenue is from users licenses and services. The operating margin for 2023 will be 59%.

The number of users is derived using a bottom up approach starting from the nuclear engineering community (our initial market). There are 16,800 nuclear engineers in the United States[3], and ANSYS (a major simulation provider) estimates that about 10% of engineers requires simulation tools[4]. We expect that there is a larger percentage of nuclear engineers that would benefit from simulation compared to the general engineering pool. However, this will serve as a good lower bound. Therefore, it is estimated that there are at least 1,680 nuclear engineers who would benefit from the V&V toolkit. Further, about 6% of ANSYS sales are in the energy sector (of which Nuclear Engineering is a subset)[5]. Therefore, we can assume that Nuclear Engineering is less than 6% of the simulation users. Therefore, we project that there are over 28,000 potential users of the V&V toolkit. We are targeting slightly over 5% penetration (1,650 total user licenses) by 2023.

3.5 Good Return on Investment

Based on our ten year projections, the DOE investment multiple will be 11.4 and the Net Present Value will be $10.6M (see the attached DOE Investment multiple worksheet). The market size and growth rate presented in this table are extended from the Pro Forma. The market share in 2019 and 2020 are from the Pro Forma and the markets share increases to 0.1% in 2030 (note, the market share was originally calculated using a market build up method described above, as there is not a good mechanism to extract the niche market size for advanced V&V tools). A stabilized operating margin of 50% was used for the years beyond 2023.

[3] Bureau of Labor and Statistics, U.S. Department of Labor, Occupational Outlook Handbook, 2016-2017 Edition, Nuclear Engineers

[4] ANSYS Investor's Day 2014: Annual Report, Ansys Inc., March 2014.

[5] ANSYS: Initiating Coverage at Hold; $90 Price Target Steady operator with strong fundamentals; valuation keeps us on the sidelines," Evercore ISI, September 14, 2016