Status Update

October 1, 2020

CONTENTS

CCAM STATUS UPDATE

This update is being submitted as required by HB30 (Chapter 1289), Item 135, L.5.:

> L.5. "CCAM shall submit a report on October 1 of each year to the Secretary of Finance, Chairs of the House Appropriations and Senate Finance and Appropriations Committees, and VIPA containing a status update of all new incentive programs, including but not limited to the following: (i) MOUs it has entered into with each university partner; (ii) funds disbursed to both university and private sector partners of CCAM, as well as any other recipients; (iii) any other agreements CCAM has entered into with representatives of the public and private sectors that may impact current and future incentive fund disbursements; and (iv) any additional information requested by the Secretary of Finance, or the Chairs of the House Appropriations and Senate Finance and Appropriations Committees"

Elements requested in L.5. are included on pages 8-11. In addition to those items requested, a brief overview has been provided below to communicate CCAM's progress and challenges. Also included in this document is a 30-day assessment by John Milton-Benoit, new CCAM CEO.

Executive Summary

- CCAM has completed it's first full fiscal year aligned with that of the Commonwealth. Final report for FY2020 audit results are expected in mid-October 2020, with an expected designation of an unqualified opinion. Audited financial statements can be provided once received by CCAM.
- The executive search committee of CCAM's Board of Directors culminated their recruiting activity with the hiring of John Milton-Benoit as CCAM's new President and CEO, effective August 20, 2020. John brings demonstrated achievement in the growth of major research programs for United Technologies Corporation. There he led the startup of a European research hub which ***delivered > $40M in program wins***. He also created and ***grew their Emerging Technologies program from zero to $20M in annual R&D funds – including $10M annually in federal funds – in four years***. His strategic leadership will be vital to CCAM's future success.
- CCAM's cash position is approximately [redacted] as of September 25, 2020. However, given the timing of receipt of annual member dues (usually January), receipt of university and industry grant funding from Virginia Innovation Partnership Authority (VIPA) is critical to CCAM cash flow in December. Procedural set-up issues in the consecration of the VIPA board by the legislature has prevented the release of already allocated funds. Thus, CCAM is currently facing a ***cash flow crunch*** [redacted] ***at year end*** if these funds are not received in December 2020. Some of this risk could be mitigated by reducing headcount and delaying accounts payable. However at this point in the year the shortfall could not be fully covered without impacting the proposed plan to recover and grow to sustainability over the next four years. CCAM is working projects eligible for these funds in anticipation of VIPA approval. A projected cash bridge summary for CY2021 is provided in the Financial Schedules section of the Appendix.
- Prior to COVID-19, CCAM was on a good trajectory in its operating plan but is now experiencing the effects of a changed economic landscape in the industrial sector.
- CCAM applied for and received $713K of SBA-PPP loan which the organization is applying for forgiveness.
- CCAM trade debt is current with the exception of contested IT related invoices which are in negotation.
- Debt repayment: a) [redacted] was paid to Virginia Tobacco Commission, b) [redacted] forgiven by University Members
- Bank of America Line of Credit renewed through September 2021 and interest is current.
- [redacted]
- With the advent of COVID-19, CCAM members began signaling pressure on their R&D budgets ***which led to a corresponding reduction in additional directed research*** at CCAM ([redacted] in 2019 vs. [redacted] in 2020) Since March, drastic headcount reduction measures have been taken by a number of CCAM members within their internal organizations.

- While CCAM anticipated some reduction in member dues for the upcoming year, the impact is now expected to be greater in magnitude as companies are faced with a decision to exit CCAM or downgrade in membership due to their reduced R&D budgets. ([redacted] in 2020 to approximately [redacted] in 2021)
- Many FY2020 university grant fund ("innovation funds") projects are now largely complete. So far, their results have supported the submission of several proposals to external funding agencies with total potential award value over three years equaling $4.34M, of which $896K is designated to CCAM. At this stage it is estimated that the win probability for these proposals is between 25-40%, resulting in expected CCAM revenues on the order of a very modest $100k per year. Details of these proposals are shown on page 10 of this report. Given the current state and based on the experience of the new CEO, ***CCAM leadership has outlined a new course of action to improve future federal funding output***.
- Pursuit of larger federally funded programs is a key strategic element and is currently underway. While a few have near-term opportunities, ***the typical cycle from concept development to marketing campaign, proposal development, award selection, and project execution takes 18 to 24 months. State support is a vital element to bridge the organization from the COVID-related recession to long-term sustainability***.
    - Near-term opportunity example: Based on prior work executed, CCAM was approached by the Office of Naval Research (ONR) to submit a few concepts that may be of interest to their initiatives. CCAM's initial response included a funding request of $3M over two years. During follow-up discussions, CCAM was asked to submit a whitepaper and encouraged to include a third year of funding to support potential work. CCAM will be issuing this whitepaper with ***a $5M funding request over three years***. If successful, this program could begin as early as 1Q 2021. Given the request for a proposal from ONR, the probability of receiving an award is estimated at 75%, thus this program is included in the operating plan (approximately $1.1M in CY2021). ***Assuming CCAM is successful in winning this award, there is a measure of risk with the timing of receipt of funds, due to potential delays in the review and selection process which is not in CCAM's control.***
    - Longer-term opportunity examples: [redacted]

John Milton-Benoit (CEO) 30-Day Assessment at CCAM

John Milton-Benoit officially joined CCAM as President and CEO on August 20, 2020 as he attended the CCAM quarterly board meeting. At the meeting he highlighted his experience at United Technologies Corporation's Research Center (UTRC) including his work as the Founding General Manager for UTRC-Ireland where he established and built UTC's European hub for research. A notable accomplishment in that role was the Public-Private Partnership he developed with the Irish government and local universities, creating an energy supply and demand management ecosystem for demonstrating technologies to enable carbon neutral neighborhoods in Europe. Along the way he raised $40M in European funds from 2010-2014. He then returned to East Hartford, CT to build the Advanced Manufacturing Program Office and grew it from scratch to $20M in annual funding, including $10M in federal funds. A key accomplishment was the establishment of UTC's $75M Additive Manufacturing Center of Excellence.

John presented his vision and 90-day plan to the board. He identified the need for a holistic vision and strategy for CCAM that aligns the organization and membership to a common vision that will deliver value to customers, reinvigorate member engagement, define a robust set of campaigns for federal government funding, and deliver value to the Commonwealth as a focal point in developing a vibrant advanced manufacturing ecosystem in Virginia. The playbook for executing this vision has already been proven by John on multiple occasions in his previous roles at UTRC. A key driver in his decision to pursue the CEO opportunity at CCAM was the fact that many of the pieces for achieving that vision are indeed already in place: an excellent technical staff at CCAM, a great higher education system to leverage essential research, strong industry membership, and state government support to power the advanced manufacturing ecosystem engine up to speed.

While there is a great foundation to build upon, there is still much to do and certain impediments exist. Since inception, CCAM has been hampered by excessive debt for a small business. Lack of liquidity, delayed hiring, and limited access to capital for manufacturing equipment has limited CCAM and exacerbated the issue. The lack of experience and processes in driving federal funding is a missed opportunity that needs to be rectified. The absence of a holistic vision of what CCAM can be has resulted in efforts that are more tactical than strategic. Despite these impediments, CCAM was recently showing strong signs of turning the corner with impactful research and financial stability (with state support) until the effects of COVID-19 on the aerospace supply chain began to trickle down. This now has resulted in significant headwind in both membership dues and additional directed research for FY2021. Economists project this downturn is expected to last through FY2022. What should not be lost in this assessment, however, is that fact that Rolls Royce and Siemens – despite their financial challenges – continue to invest research dollars in CCAM. This is a proof point to the value that CCAM adds to their organizations and the promise CCAM holds for invigorating the advanced manufacturing footprint in Virginia, with the correct vision and state support to assist CCAM in managing through the COVID-19 dip.

Realizing the promise that many have long-envisioned for CCAM requires focus in three key areas to be successful:

- Development of a holistic vision for CCAM that aligns the organization members and partners
- Concerted efforts on winning federal funding that can establish multi-million dollar investments in technical capability that can be then leveraged by industry
- Continued investment from the state to get through COVID-19 headwind and enable CCAM to execute the strategy for realizing the shared vision of a vibrant advanced manufacturing ecosystem in Virginia

CCAM Vision

This first key area is already underway. The CEO's 90-day plan begins with developing a holistic vision and strategy for CCAM. This effort requires assessing CCAM's technical capabilities, understanding the application spaces where these capabilities provide significant value to our members, and articulating a grand vision where the interplay of these capabilities and applications are a natural fit for a diverse industry membership base. In September, the CEO met with every staff member at CCAM and held technical deep dives to understand capabilities. This effort has identified a clear vision and message around intelligent manufacturing and the digital thread towards adaptive and distributed manufacturing. Additive, surface engineering, machining and robotic manufacturing processes are key technologies that tie the intelligent factory to the specific applications of our member companies. Further, this platform vision inherently outlines campaign opportunities for federal funding while enabling CCAM to diversify the industrial segments of our future membership companies without diluting focus and expertise. For example, the framework describes an architecture and process for distributed manufacturing of 3-D printed repair technologies for the Navy, enabling them to print or repair a component anywhere in the world while verifying function and tracing material properties and specifications required for certification. This same platform can be modified for similar use in other industries, including medical device and implants, or a continuous pharmaceutical manufacturing process such as that envisioned for the Petersburg area. [redacted] To enable continued growth in technical capability, CCAM will also need to explore avenues to acquire manufacturing equipment and their installation costs, through grant applications and industry donations.

Winning Federal Funding

The second key area targeting significant awards in federal funding is also in progress and requires continuing effort and improvement. As mentioned above, the proposed vision enables a platform for generating multiple DOD campaigns that will provide value to the federal government while enhancing the technical capabilities that CCAM can offer to industry members in the future. To generate compelling campaign concepts, it will be imperative for CCAM to leverage the talent in Virginia's higher education system, CCAM's industry member base, and state support to accelerate these efforts. The plan to date where the higher education system is to drive federal funding at CCAM has largely fallen flat. In the 2019 Operating Plan, universities projected CCAM funding levels of $1.6M by 2021 driven by the efforts of Research Professors placed at CCAM and with the support of state innovation funding. The planned Research Professor staffing is currently at 50% and has resulted in a very modest projection of $300K in external funding awards for 2021. The current innovation program funded by the state has begun to show some notable improvement, largely due to a few motivated faculty that have generated the lion's share of the future opportunity. This uptick is certainly a result of the state innovation program funding incentives. While these new positive interactions are welcome, it is clear that ***CCAM needs to position itself as an active driver of federal program campaign development to achieve an order of magnitude improvement in federal revenues.*** The new focus on vision and strategy of the intelligent factory will enable CCAM to do just that, leveraging University capabilities in holistic federal government programs with CCAM and industry. CCAM is currently developing a proposal for the Office of Naval Research which is a prime example of how this vision can generate federal programs. While not guaranteed to be awarded to CCAM, this particular proposal was requested from CCAM by the program manager at ONR, which is a proof point to the value that CCAM can provide. If successful, this program would generate $5M in government funding for CCAM over 3 years and would leverage technical content from VA-based universities and include CCAM industry members, either as active performers or industrial advisors to the program. At a minimum – note that this near term timing of a potential award is atypical, as elaborated below – development of this concept in the proposal writing will enable CCAM to market similar campaigns across the DOD. In the experience of the CEO, the cycle from campaign concept marketing to proposal to successful award to funding

in-house is typically 18-24 months. Sustained federal funding to CCAM can certainly exceed $5M annually, but typically this funding ramp-up would begin in earnest in 2 years. To bridge this gap, state funding is needed to drive this effort. This would support the hiring of a dedicated person for federal business development (BD) and their related travel and campaign development expenses for marketing programs within the federal government organizations. The potential ROI on an individual with a proven track record in the federal grant and award space will be significant. This person would also institutionalize the required BD processes within CCAM to ensure quality and efficiency of efforts. One of the deficiencies that CCAM has had is a lack of someone with a solid understanding of the federal award landscape who is actively meeting with program sponsors to market CCAM. This activity is vital to shaping a program for the DOD and is an essential element to consistently win large awards. This dedicated effort will help deliver the $3.5M in federal awards planned by 2024. Finally, CCAM respectfully requests flexibility to use state funding that is made available, whether from the existing industry match funding or the existing general operating appropriation, to augment federal program funding. This would help bridge CCAM to post-COVID-19 stability while federal award programs mature.

Commonwealth Support

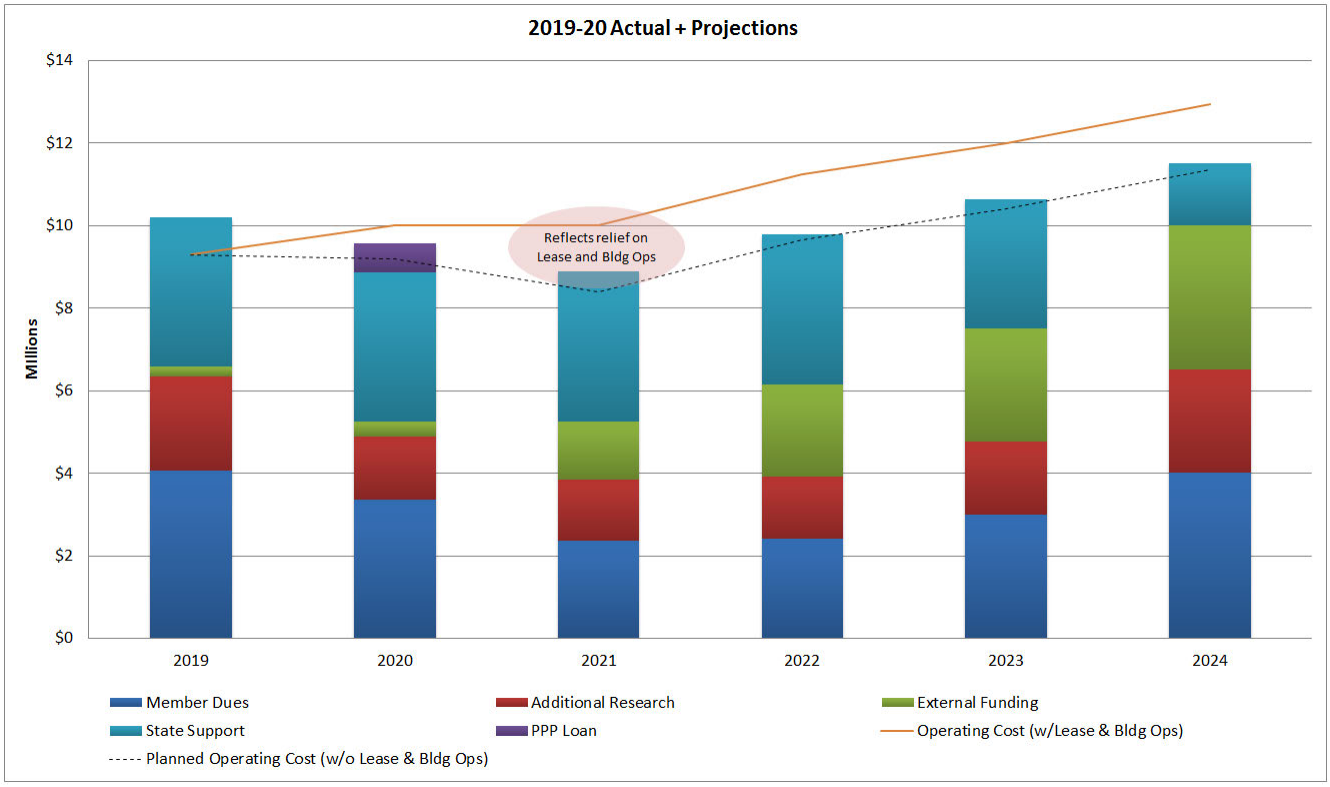
The third key area is the continued support from the Commonwealth of Virginia. As noted above, state investment is a key element to bridge CCAM to sustainability and realize the envisioned vibrant advanced manufacturing ecosystem that delivers significant ROI for the Commonwealth. CCAM would benefit from a long-term solution to the current oversized building lease and operational costs. The state currently provides funding to offset these costs, which is critical support to CCAM. These funds are set to decrease beginning in FY2022, which would result in financial difficulty for CCAM in this COVID-19 downturn. Financial headwinds associated with this downturn result in the need for continued state support at current levels. [redacted]

For the remainder of FY2021, assuming this above concern regarding the release of VIPA funding is addressed, financial pressure remains. This is driven by the lack of federal funds and significant COVID-19 headwinds for our member companies. Some companies have been forced to pull out of CCAM [redacted] while others, [redacted] have or are expected to drop to a lower membership tier. Other companies, [redacted] have maintained their membership level despite their financial pressure, but have informed CCAM that they will not be able to perform as much additional directed work as they have in previous years. State matching funds on additional industry directed research have been a key enabler in maintaining a significant percentage of this work at CCAM, thereby reducing the negative impact that would have otherwise been passed on to CCAM due to the current economic conditions – particularly in the aerospace sector. This financial pressure, however, is still rather significant for CCAM. [redacted]

CCAM now has a strong vision and solid trajectory for federal funds that will build capabilities which can then be leveraged by the manufacturing footprint in the Commonwealth in the 24-month timeframe. To reach this state, near term financial pressure needs to be addressed. A solution which would alleviate annual building lease and operational cost ($1.6M) is desired. Continued investments in university grant ($0.6M) and industry grant ($1.1M)

funding need to be maintained. These funds have had direct positive impact – particularly during the COVID-19 economy. As an example, [redacted] was set to join CCAM at the Strategic level. Budget pressure resulted in them informing CCAM that they would have to pull back and consider membership in the future. ***State matching funds are the primary reason*** [redacted] ***was able to manage their budget and join CCAM in 2020. There is considerable upside potential in additional directed research and upward membership movement for CCAM in CY2021 – all made possible by state matching funds.*** To execute the plan for achieving an order of magnitude improvement in obtaining federal funds, discussed in the paragraph above, maintaining the annual state appropriation for operating and lease expenses at current levels ($1.925M) is requested. This appropriation would be used to bridge the COVID-19 gap and support the development of campaigns that will lead to successful awards. An effective external funding program is vital in order to reduce the need for future state support.

Figure 1



In total, these efforts and investments are expected to generate growth of CCAM annual revenue to $10M by 2024. Additional ROI is expected as CCAM is leveraged to provide technical capabilities to SMEs in the state and growth of the manufacturing base within the Commonwealth. The plan in place will enable the realization of the promise first envisioned for a vibrant advanced manufacturing ecosystem in the Commonwealth, with CCAM as a key player in driving that vision forward.

HB30 (Chapter 1289), Item 135, L.5. Requirements

(i) MOUs with university partners

One MOU, signed January 2019, between CCAM and its Organizing University Members was included in CCAM's Operating Plan submitted to VEDP in July 2019. This referenced university placement of Research Professors and Graduate Research Assistants at CCAM, and university commitments for innovation funding. There UVA, VCU, VSU and VT each committed to placement of Research Professor at CCAM. An MOU was since established between CCAM and ODU in December 2019 to satisfy their "placement" of a Research Professor (see Appendix).

(ii) Funds disbursed to university and private sector partners of CCAM

For fiscal year 2021, CCAM oversight has transitioned from Virginia Economic Development Partnership (VEDP) to Virginia Innovation Partnership Authority (VIPA). To date, VIPA has not been fully sanctioned to approve release of industry and grant funding. *However, CCAM has begun internal approval and commencement of projects to ensure that revenue may be realized within the fiscal year*.

Item 135, L.2. – Private Sector Incentive Grants

FY2020: To date, $1,016,507 of the $1,100,000 available for private sector incentives has been deployed in research match funding and new CCAM membership. These incentives have allowed CCAM to participate in more diverse research programs [redacted]. These incentives were also a critical element in securing [redacted] and [redacted] in FY2020. Both have significant upside potential for CCAM revenue. A summary of deployed funds is provided in the table below, and their details submitted to VEDP.

Industry Member	Grant Funding	Detail
[redacted]	$ 64,894	Project D-279
[redacted]	$ 79,996	Project D-280
	$ 50,672	Project D-295
	$ 33,500	Project D-302
	$ 51,441	Project D-304
	$ 66,000	Project D-342
	$ 35,000	Project D-256
	$ 50,000	Project D-286
	$ 99,529	Project D-105
	$ 120,475	Project D-264
[redacted]	$ 100,000	Project D-323
[redacted]	$ 100,000	New Membership
	$ 22,500	Project D-354
	$ 27,500	Project D-363
[redacted]	$ 40,000	Project D-331
[redacted]	$ 75,000	New Membership Signed (Year 1)
	$ 1,016,507	

FY2021: There is $1,183,492 available for private sector incentives in FY2021 which includes the remainder of FY2020 funds. Planned deployment of FY2021 industry grant to date is in the table below.

Industry Member	Grant Funding	Detail
[redacted]	$ 90,262	Project D-381 (signed)
	$ 19,760	Project D-384 (signed)
	$ 42,828	Project D-385 (signed)
	$ 62,652	Project D-356 (scoped)
[redacted]	$ 150,000	Project D-374 (in development)
[redacted]	$ 75,000	New Membership Signed (Year 2)
[redacted]	$ 75,000	New Membership Proposed (Year 1)

$ 515,502

Item 135, L.3. – University Research Grants

FY2020: All $600,000 available for university research grants was deployed at CCAM in the execution of innovation projects in partnership with CCAM Organizing University Members. A one-to-one match has been made by universities to fund their portion of research on their campuses. A summary of designated funds is provided in the table below, and details have been submitted to VEDP.

University Member	Grant Funding	Detail
University of Virginia	$ 250,000	Projects E-035, E-036, E-037
VCU	$ 130,000	Projects E-038, E-039, E-040
Virginia Tech	$ 120,000	Projects E-042, E-043, E-044
Virginia State	$ 50,000	Project E-041
Old Dominion University	$ 50,000	Project E-046

$ 600,000

So far, results of the first year innovation fund projects have led to several collaborative proposal submissions to external funding agencies ($4.34M potential award value, with $896K to CCAM). This activity is summarized below and provided in more detail in the appendix.

Proposals Submitted and Awaiting Outcome

Agency	Lead	Total Budget	CCAM Portion	Submitted	Title
ARPA-E	UVA	$ 2,272,884	$ 303,488	Sep 2020	"High Entropy Rare-earth Oxide (HERO) Coatings for Refractory Alloys" in collaboration with researchers from CCAM and from Virginia Tech.
NSF	VT	$ 568,258	$179,878	Feb 2020	"NRI: FND: Data Sharing and Transfer Training for Sensing-Actuating and Human-Robots Coordinations: Methodology and Open-Source Infrastructure."
CESMII	VT	$150,000	$30,000	Mar 2020	"Building a Trained and Agile Workforce for the Future Intelligent Factory."
NSF	VT	$ 499,784	$80,000	Jun 2020	"FMSG: Self-Calibrated Manufacturing: Methods, Algorithms, and Testing"
NSF	VT	$849,563	$ 302,771	Jun 2020	"Collaborative Research: CPS: Medium: Tensor-Enabled Correlation"
		$ 4,340,489	**$ 896,137***	** 896K x 33% win rate over 3 years ~ $100K/year*	

Proposals Submitted but Denied

Agency	Lead	Total Budget	CCAM Portion	Submitted	Title
ONR	UVA	$ 150,000	$ 100,000	Mar 2020	"Sensor-Driven Adaptive Modeling of the Directed Energy Deposition Process for Assessing and Assuring Process Reliability"
		$ 150,000	**$ 100,000**		

Proposals in Active Development

Agency	Lead	Total Budget	CCAM Portion	Submission	Description
NSF	VSU	$ 400,000	$ 55,000	Oct 2020	NSF Solicitation #20542: Historically Black Colleges and Universities - Excellence in Research (HBCU - EiR)
NSF	UVA	$ 250,000	$ 75,000	Open BAA	The results in non-equilibrium kinetics developed by Zhou and Wang under this project, combined with adaptive sensing, offers significant opportunities to advanced process reliability.
NSF	ODU	$ 350,000	$ 55,000	Letter of Intent Oct 2020 Full proposal Jan 2021	I-STEM: STEM principles education for underrepresented groups through the use of human-machine accessible interfaces applied to CNC tasks
		$ 1,000,000	**$ 185,000**		

FY2021: To date $539,625 of $600,000 available for university research grants has been deployed at CCAM in the execution of innovation projects in partnership with CCAM Organizing University Members. A one-to-one match has been made by universities to fund their portion of research on their campuses.

University Member	Grant Funding	Detail
University of Virginia	$ 250,000	Projects E-052, E-053, E-054
VCU	$ 50,000	Projects E-063
Virginia Tech	$ 108,819	Projects E-057, E-058, E-059
Virginia State University	$ 130,806	Project E-055, E-056, E-060
Old Dominion University	$ -	Project scoping expected later this year
	$ 539,625	

(iii) Other agreements entered into with public and private sectors

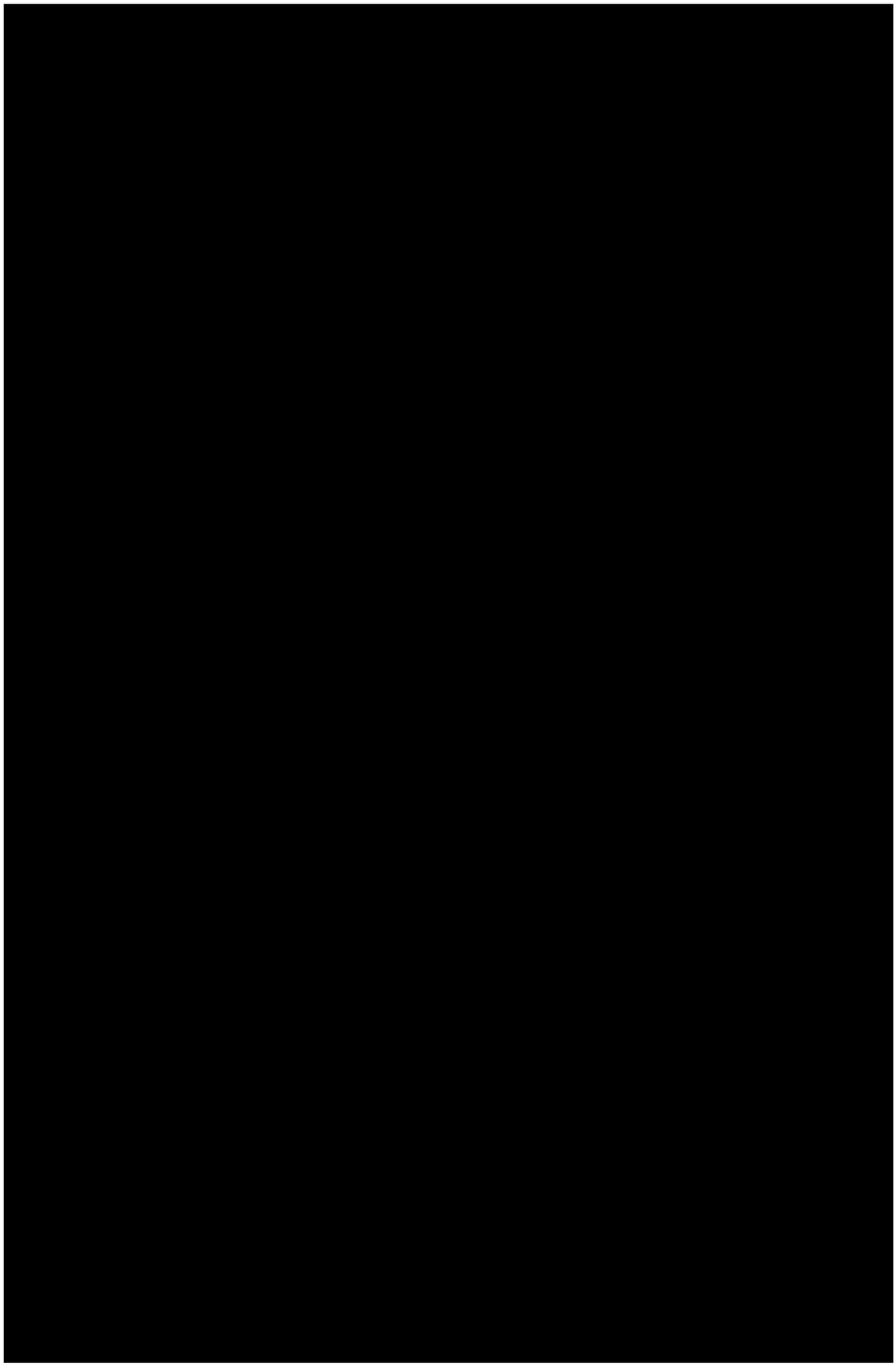
CCAM has not entered into any agreements with representatives of the public or private sectors that would impact current and future incentive fund disbursements.

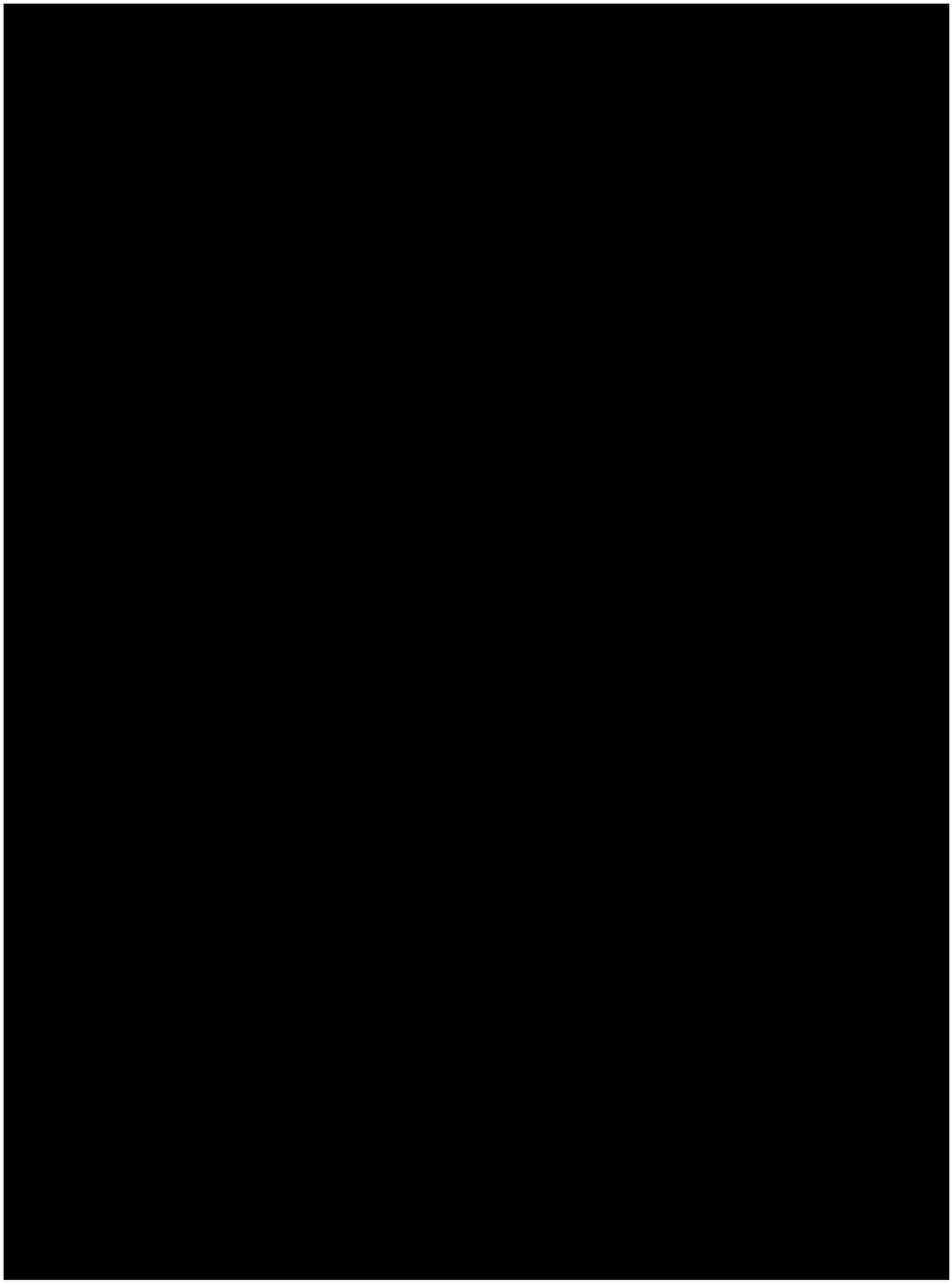
(iv) Additional information requested

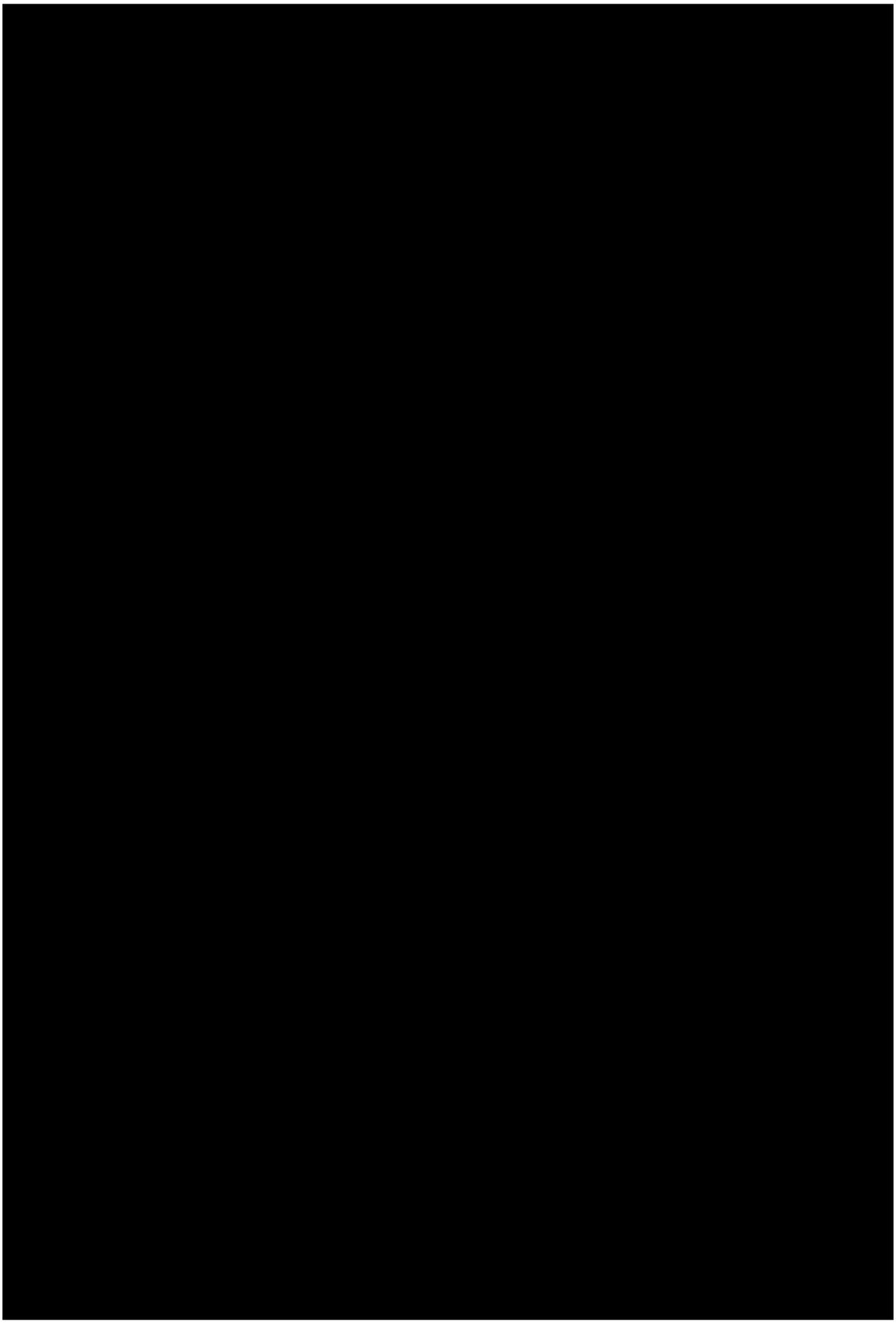
No additional information has been requested at this time.

APPENDIX

Financial Schedules







John Milton-Benoit Resume

John Milton-Benoit

CEO / VP Research & Innovation / Business Development

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Executive with a passion for innovation and a proven track record of **developing and deploying disruptive technologies** that meet business needs in global marketplaces. Builder of world-class capability and technology innovation organizations and ecosystems in **the US and internationally** – in advanced manufacturing, aerospace, energy and security. A strategic thinker that **thrives in complex and ambiguous environments, delivering near-term business value** while executing long-term vision.

Demonstrated Achievements

- ✓ *Led all aspects of the start-up of UTC's European hub for research, providing Strategic Leadership and Execution resulting in EU R&D **program wins > $40M**.*
- ✓ *Created and grew UTRC's Emerging Technologies Program **from zero to $20M annual R&D funds** in 4 years and delivering **~ $750M in value creation**.*
- ✓ *Guided the model-based design of pilot ejection seats with a short turnaround time for **$500 Million in sales opportunity, winning a sole source selection** in 2019.*
- ✓ *Reached across organizational boundaries to propose, win, and then **start-up UTC's $75M Advanced Manufacturing Center of Excellence**.*
- ✓ *As a business owner, established a strategic partnership to enable cross-marketing of client services, resulting **in 400% increase in revenue** over 3 years.*

Core Competencies

✓ Research & Innovation	✓ Strategic Leadership	✓ Avid Mentor
✓ Product Development	✓ P&L, Operations	✓ User-centric Design
✓ Strategic Planning	✓ Negotiation	✓ Customer Outreach
✓ Business Development	✓ Strategic Partnerships	✓ Change Leadership

Executive Experience

United Technologies Research Center (UTRC) October 2000 – December 2019

Senior Director, UTRC Carrier Innovation Program Office, Sep 2018 – Dec 2019.

Responsible for technical and business leadership for all Carrier-related R&D activities across UTRC, resulting in the development and implementation of innovative technologies for the business operating units of Carrier.

- Program Leader responsible for strategy and capabilities for "Frictionless Buildings" – the convergence of Machine learning, WSNs, autonomous user authentication and trust for the seamless access and operation of connected buildings.
- Program Leadership for a low-GWP (Global Warming Potential) mixed flow chiller, ***increasing efficiency from 85 to 91% while reducing size and cost by 25%*; won an Outstanding Achievement Award**.
- As the executive champion of UTRC's Innovation Process, led the process transformation to ***increase focus and disruptive impact for UTC's businesses***.

- Led Change – aligned to UTC's planned Carrier spin-off, ***strategically unwound the $30M Program to retain talent and transfer skills*** and capabilities to Carrier.
- Defined the strategic reorganization of funded programs for incorporation into the aerospace program offices.

Senior Director, UTRC Advanced Manufacturing & Service Technologies / Emerging Technologies Program Office, Sep 2014 – Sep 2018.

Created and executed the strategic direction in advanced manufacturing and service technologies, resulting in ~ ***$750M of created value***. Developed manufacturing and digital strategic roadmaps and world-class capabilities in additive manufacturing, robotics/autonomous manufacturing, collaborative robotics, machine intelligence and cyber physical security. Expanded UTRC's manufacturing and service impact on UTC BUs. Member of UTC's Mfg Council.

- **Started and grew to $20M annually**, with $10M in gov't-funded research in cyber physical security, autonomous systems, advanced manufacturing and robotics.
- Led the cross-UTC team strategy and proposal for a **$75M Additive Manufacturing Center of Excellence**. Led the **start-up and build-out** - including strategy and roadmaps for technology, equipment, processes and training across UTC.
- Developed modeling and analytics capabilities deployed in each of UTC's business units, including:
  - Machine Learning and Video Analytics that enabled **PW to ship ~ $100M of additional GTF Jet Engines**,
  - Data Analytics and Streaming for Prognostics and Health Monitoring that enabled an **enhanced service business model** for Otis,
  - Analytics of Boeing 787 equipment in-flight data that drove key **maintenance and operation business insight** for United Technologies Aerospace Systems,
  - Powder Bed Fusion AM Process Modeling that enabled the 1st ever 3D print and successful test completion of a small jet engine in **6 months, instead of 2 years**.
- Booked record sales of $30M as Acting Sr. Director of the UTAS Program Office.
  - Oversaw the rapid model-based design of pilot ejection seats, resulting in a 2019 sole source selection for Collins - **a $0.5 Billion sales opportunity**.

Founding General Manager, UTRC Ireland, Cork, IE, 2010 - 2014.

Co-wrote winning proposal for Irish government funding. As Founding General Manager, responsible for ***all aspects of start-up*** and subsequent $10M of annual program content in leading UTRC's European hub for research and development.

- Responsible for all operational, financial, HR, and technical aspects of creating a new research and development organization, **hiring and mentoring 40 technical staff (now ~ 100)**; received ACE Gold internal and external customer feedback.
- Championed Design Thinking, deploying VOC-driven Innovation to the businesses of UTC, e.g., a new, AI-enabled, role-based security solution for Lenel **to reduce manual access control management by 80%**.

- Negotiated agreements with universities and the Irish Government to establish a national sustainable energy test bed for integrated security and energy systems. Officially launched by Ireland's Minister for Research and Innovation in Nov. 2013.
- **Won EU-funded programs totaling > $40M** to support business-driven research agenda. Funded programs include:
  - **SPARKS** - Smart Grid Protection Against Cyber Attacks (project-sparks.eu)
  - **ANASTACIA** - Advanced Networked Agents for Security and Trust Assessment in CPS / IOT Architectures (anastacia-h2020.eu)
  - **ELSA** - Energy Local Storage Advanced system (elsa-h2020.eu)
  - **Factory 2 Fit** - Worker-Centered Solutions for the Factories of the Future (factory2fit.eu)
  - **LASIE -** Large-Scale Information Exploitation of Forensic Data **(**lasie.eu**)**
- Expanded the research portfolio to include aerospace, established a Center of Excellence for Cyber-Physical Systems.
- Liaised with Irish and EU government officials, communicating UTC/UTRC interests in Europe, laying the groundwork for a ***$12.3M CleanSky program win***.

President & Founder, **IntelliTech Engineering** – a design and analysis consulting firm specializing in complex, nonlinear, finite element analysis, East Hartford, CT, 1996–2000.

Managed all phases of the consulting firm, including: *Full P&L responsibility, Marketing, Pricing, Hiring, and Project Management*. Established strategic partnership to enable cross-marketing of client services, resulting in ***400% increase in revenue over 3 years***.

Modeling and Analytics driven customer successes:

- Reduced the number of failures per lot by 500% for a Big-3 auto parts supplier.
- Increased the number of cycles to failure by 125% (from 270k cycles to over 600k cycles) while increasing flow rate by 15% for a pump diaphragm manufacturer.
- Achieved 2X performance improvement for a leading saw blade manufacturer. New tooth forms incorporated across multiple product families. *Record sales* due to these products being recognized as the *market leader* by customers.

Education & Innovation

M.S.M.I.E., B.S.M.E., University of Massachusetts, Amherst, MA

University of Virginia, *UTC Darden Emerging Leaders Program*
Northwestern University, *Shaping Innovation Leaders Executive Management Program*
TLDG, *Leadership Development Training @ West Point*

Inventor on more than two dozen patents

Led/Mentored teams to UTRC Outstanding Achievement Awards six times, including for a *Low-Power Lock* for UTC Fire & Security, *Establishing UTRC-Ireland: UTC's European Hub for Research*, & *Model-Based Design of the ACES 5 Ejector Seat* for Collins Aerospace

Update on University Commitments

As outlined in the "Plan to Operationalize & Implement University Member Enhanced Engagement" the university members committed to activities designed to strengthen CCAM-University engagement in 3 primary areas: CCAM Research Professors, graduate research assistants (GRAs), and Innovation Projects. Specifically, the commitments are as outlined below:

- Identify & hire four (4) Research Professors associated with CCAM Strategic Focus Areas and aligned with research strengths of the university partners.
- Identify & hire nine (9) Graduate Research Assistants to be primarily working at CCAM.
- Create an Innovation Fund ($600K per year total from Universities, matched by state funding) to seed research activities at the Member Universities that are aligned with CCAM Industry Member needs and have potential for external funding.

The heat maps below show the status of each of these activities as of August 2020 (those reflecting FY 2020), and the evolution as of August 2021 (FY 2021).

University	Research Positions	FY 2020 GRA(s)	FY 2020 Innovation Funds
VCU	[redacted] started July. 2019	Two GRAs working at CCAM	Three projects initiated ($135K)
University of Virginia	[redacted] started Jan. 2019	Recruited but no GRAs at CCAM. Lead to negotiation of a new approved plan.	Three projects initiated ($250K)
VSU	Position posted and recruiting candidates, including using CCAM search firm.	1 Student GRA at CCAM	One project initiated ($50K)
Virginia Tech	Offered extended and candidate declined.	1 Student GRA at CCAM	Three projects initiated ($120K)
Old Dominion University	CCAM/ODU have agreed to flexible resourcing	CCAM/ODU have agreed to flexible resourcing for the single committed position	One project initiated ($50K)

University	Research Positions	FY 2021 GRA(s)	FY 2021* Innovation Funds
VCU	[redacted] started July. 2019	Two GRAs working at CCAM	7 Proposals Submitted; 1 projects selected & initiated ($50K)
University of Virginia	[redacted] started Jan. 2019	2 Started over summer as interns and have transitioned to GRAs under new agreement	6 Proposals Submitted; 3 projects selected with 2 merged & initiated ($250K)
VSU	1 candidate identified and offer extended	1 started at CCAM in the Fall and making headway on identifying 2nd	6 Proposals Submitted; 3 projects selected & initiated ($150K)
Virginia Tech	Search on hold due to VT hiring freeze	No candidates for the 2 committed positions	3 Proposals Submitted; 3 projects selected & initiated ($100K)
Old Dominion University	CCAM/ODU have agreed to flexible resourcing	CCAM/ODU have agreed to flexible resourcing for the single committed position	Planning a selection by end of CY 2020, single project expected ($50K)

On Hold/ Needs assistance | Beginning Stages | Final Stages | Complete

All FY2020 Innovation Funds committed and projects are wrapping up

The hiring of CCAM Research Professors at VSU and VT has been slower than anticipated and has negatively impacted progress in building solid relationships with the Universities. Also, there has been significant leadership turnover at Virginia Tech for those interfacing with CCAM and they have a university hiring freeze at the moment, so their activities are delayed. CCAM Research Professors will have an important role in leading proposal development themselves in activities where CCAM has a majority/lead role. An example of one such activity from the past year is the NSF Major Research Instrumentation (MRI) program submission "MRI papers: Acquisition of a Binder Jetting 3D Printer for Research and Teaching at VCU" with a proposed budget of $917,486, This proposal was to acquire an ExOne M-Flex® 3D printer to be housed at CCAM. This was a collaborative proposal with VCU, UVA and CCAM and this opportunity is open to CCAM solely due to their partnership with member universities, as the MRI programs are for universities. This project would have ensured access to new additive manufacturing technology that would lead to research in the areas of nano-surface technology, physics-optimized processing of 3-D printed magnetic components for solid-state cooling devices, translational research in the area of medical device development, examination of microstructure characteristics and fractal analysis of 3D printed functional alloys, machine learning and predictive data analytics of the additive manufacturing process. [redacted] The team is planning a follow-up proposal which will be submitted in January 2021.

Another activity that has demonstrated the ability of CCAM Research Faculty to establish a broader footprint of advanced manufacturing within the CCAM-University Partners-Industry Member enterprise, is the recent study by DARPA on materials and manufacturing for hypersonic applications. [redacted] was requested by Astro America to participate in a DARPA "Seedling Program", along with other faculty at the University of Virginia and Virginia Technological University, to develop a concept for flexible advanced manufacturing of components for hypersonic systems. The study would be used by DARPA and other government organizations to establish an Industry-University-Government initiative in this important technology. Because of the strong presence of Dr. Martukanitz and other faculty, the State of Virginia was considered to be a regional hub of technology applicable to hypersonics. Discussions are ongoing regarding the potential of establishing an active initiative by DARPA, Air Force, and NASA regarding an accelerated development, manufacturing, and testing facility for hypersonic components. The presence of NASA Langley Research Center, major research organizations, and a public-private partnership dedicated to advanced manufacturing in Virginia is under strong consideration to participate in this venture.

The University Working Group had been meeting regularly, but COVID did significantly impact the rate of progress, as both CCAM and universities were shut down with no access to research facilities for some time and university leader efforts were re-directed to managing the crisis and the transition to on-line learning. Regular working group meetings resumed in May. A few very positive outcomes from last year include development of a widely accepted call-for-proposals and scoring rubric for selection of Innovation Award winners, and a new agreement for effective use and deployment of the committed GRA resources. This new GRA agreement, combined with work the previous year focused on how GRAs are utilized on CCAM teams and clarifying CCAM's responsibility to reach out to any private sponsor to ensure students are able to publish their research (after review from the sponsor). [redacted] worked with CCAM to develop an "on boarding" process for GRAs which includes training on NDAs, setting expectations, work-study balance and a meet-and-greet. All these efforts will enhance participation in this program for years to come.

Most 2021 CCAM Innovation award projects were launched over the summer or at the start of the fall semester and the 2020 CCAM Innovation projects are just wrapping up (following some COVID delays). Reports on the 2020 projects are given in the appendix along with a table of opportunities and benefits for each project. These tables show the variety of benefits derived from these activities, and also document some of the preliminary work that is taking place laying the foundation for future external research funding, a goal of this program. It is notable that many of the already submitted proposals are to NSF, where preliminary results and solid built relationships with the program manager are less of a

requirement for funding. Thus, proposals can be submitted much closer to project ideation. The Department of Defense agencies, on the other hand, rely heavily on personal relationships - which require development - before white papers are submitted, only then potentially to be invited for full proposals. Indeed, DOD funding often comes from informed discussions with program managers, published research results, and proposal activity and these efforts are necessary to get CCAM, University researchers and CCAM collaborators at the table for discussions so that they can successfully develop the proposals that specifically address the program manager's needs. These tables are meant to document the steps being taken to develop the foundation for a successful future submission. It should be noted that at this point many projects are just wrapping up, with preliminary data still being examined and prototypes being finalized.

A summary table, including only the proposals that have been submitted or those that are in active development, is provided at the start of the Appendix. As of the writing of this report there were already five proposals to external funding agencies, totaling $4,340,489 submitted and in review led by University Principle Investigators with CCAM collaborators with proposed sub-contracts to CCAM totaling $896,137 (representing 21% of the total proposed funds). This does not include the single PI young investigator award for $495,987, which does not allow sub-contractors. In addition, there has been one full proposal submitted with CCAM collaborators which has already been denied (as well as several white-papers), and there are three collaborative proposals in active development. With the seed projects just now wrapping up, it is now that most proposal activity will begin in earnest and it is anticipated that submissions based on these projects may extend over the next year (at least) based on the results of innovation projects executed over the past year. Once submitted, an average review period would be six months for most funding agencies. We are hopeful that the external funding portfolio will continue to build, along with the sub-contract ratio to CCAM as the relationships initiated during these seed grants are solidified.

Detailed Funding Proposal Activity Resulting from FY2020 University Grant

Provided here is a summary of all the proposal activity generated from the FY2020 CCAM-University Innovation awards separated by pending, denied, and in development.

Proposals Submitted and Awaiting Outcome

AGENCY	LEAD(S)	TOTAL BUDGET	CCAM SUB-CONTRACT	DATES	TITLE AND DESCRIPTION
ARPA-E	Opila (UVA) and Zimmerman (CCAM)	$2,272,884	$303,488	Submitted proposal Sept. '20	ARPA-E proposal, "High Entropy Rare-earth Oxide (HERO) Coatings for Refractory Alloys" in collaboration with researchers from CCAM and from Virginia Tech.
National Science Foundation	Yue (VT) and Schroeder (CCAM	$568,258	$179,878	Submitted proposal on 02/2020	The NSF NRI 2.0 program proposal, "NRI: FND: Data Sharing and Transfer Training for Sensing-Actuating and Human-Robots Coordinations: Methodology and Open-Source Infrastructure." *Pending.* This project focuses on data sharing and transfer training in advanced manufacturing systems.
Clean Energy Smart Manu-facturing Innovation Institute ("CESMII")	Camelio (VT), Yue (VT), Kong (VT), Roberts (CCAM)	$150,000	$30,000	Submitted proposal on 03/2020	CESMII proposal, "Building a Trained and Agile Workforce for the Future Intelligent Factory." *Pending.* This project focuses on building a trained and agile workforce for smart manufacturing through competency-based learning modules.
National Science Foundation	Yue (VT), Fang (NCSU), Vaziri Sereshk (CCAM), Xie (VT)	$499,784	$80,000	Submitted proposal on 06/2020	NSF FM proposal, "FMSG: Self-Calibrated Manufacturing: Methods, Algorithms, and Testing". *Pending.* This project focuses on developing self-calibrated manufacturing methods, algorithms and testing prototype.
National Science Foundation	Yue (VT), Bakker (CCAM), Schroeder (CCAM)	$849,563	$302,771	Submitted proposal on 06/2020	NSF CPS proposal, "Collaborative Research: CPS: Medium: Tensor-Enabled Correlation". *Pending.* This project focuses on developing data analytics for advanced manufacturing systems.
National Science Foundation	Yue (VT)	$495,987	$15,000 (for manu-facturing day)	Submitted proposal on 08/2020	An early career single PI (a requirement) NSF proposal. "CAREER: Towards Quality Improvements in Manufacturing and Health Care: Hierarchical Correlation Analytics for Transfer Learning". *Pending.* This project focuses on developing quality control technologies for complex systems, especially advanced manufacturing.

Proposals Submitted but Denied

AGENCY	LEAD(S)	TOTAL BUDGET	CCAM SUB-CONTRACT	DATES	TITLE AND DESCRIPTION
ONR Manu-facturing Science	Martukanitz (UVA), Plotnikov (CCAM), and Balachandran (UVA)	$150,000	$100,000	Proposal submitted Mar, 2020. Proposal declined.	"Sensor-Driven Adaptive Modeling of the Directed Energy Deposition Process for Assessing and Assuring Process Reliability". Proposal not awarded.

Proposals in Active Development

AGENCY	LEAD(S)	TOTAL BUDGET	CCAM SUB-CONTRACT	DATES	TITLE AND DESCRIPTION
National Science Foundation	Chen (VSU), Melissa Tsui (CCAM), Huda Al-Ghaib (CCAM), and Ben Zimmerman (CCAM)	Estimated $400,000 for 3 years	~$55,000	Letter of Intent submitted July '20. Proposal to be submitted Oct. '20	Letter of Intent submitted July 22. We are preparing the proposal to submit toward NSF Solicitation #20542: Historically Black Colleges and Universities - Excellence in Research (HBCU - EiR). The proposal will be submitted by the deadline Oct. 6, 2020
NSF Civil, Mech., and Man. Innovation	Zhou (UVA), Wang (UVA), Martukanitz (UVA), and Plotnikov (CCAM)	$250,000	~$75,000	Open BAA	The results in non-equilibrium kinetics developed by Zhou and Wang under this project, combined with adaptive sensing, offers significant opportunities to advanced process reliability. Proposal being formulated.
NSF INCLUDES Alliances Solicitation (NSF 20-569)	Jessica Johnson (ODU), Hector Garcia (ODU), and Tim Bakker (CCAM)	$350,000	~$55,000	Letter of Intent Oct 2020 Full proposal Jan 2021	This NSF proposal with a working title of "I-STEM: STEM principles education for underrepresented groups through the use of human-machine accessible interfaces applied to CNC tasks". CCAM is a collaborator and will be part of the Alliance to implement the proposal.

Opportunities from the FY2020 CCAM-University Innovation Program

Project

University Collaboration: Virginia Polytechnic Institute and State University

Understanding the Mechanisms of Machining Tool Wear by Integrating Data Analytics with Advanced Manufacturing

Participants

VT: Drs. Xiaowei Yue, Zhenyu (James) Kong, and Jaime Camelio (Industrial and Systems Engineering)

CCAM: Dr. Kaushik Joshi

Project Description/Technical Approach

The goal is to create a data/physical integration strategy to link heterogeneous data with physical models of machining tool wear, develop interpretable machine learning methodologies for understanding the mechanisms of machining, advance dynamic optimization based on critical features and pertinent knowledge, e.g., enable better anomaly detection, process monitoring and system prognostics.

Benefits for CCAM Network (OUM and OIM)

The product most greatly benefits CCAM industry members by enhancing CCAM's capability on Adaptive Automation Systems, and Machining Technologies, specifically on understanding the mechanisms by integrating data analytics with physical models, which is a promising domain with broad potential applications.

Expected Deliverables

This project will develop a systematic strategy to integrate data analytics with advanced manufacturing, especially with machining tool wear as an application case.

- Development of design of experiment (DOE) to identify machining operation, material, tooling and types of data signals.
- Development of data analytics, including mathematical models, theoretical exploitation, computational algorithms, and open-source codes.
- Validation of the proposed methods
- Immediate pursuit of external funding

Required Equipment and Rough Cost Estimates

- POP 12 months
- Total budget $120,000
- $60,000 VT/$60,000 CCAM
- Utilization of automated tool wear measurement (ATWM) to collect real-time monitoring data during machining and tool wear process at CCAM
- CCAM Technical Point of Contact Dr. Kaushik Joshi, VT Technical Point of Contact Dr. Xiaowei Yue

Opportunities and Benefits

VT-CCAM: Understanding the Mechanisms of Machining Tool Wear by Integrating Data Analytics with Advanced Manufacturing

Opportunities and Benefits	Agency or Company	Lead(s)	Value	Action Date	Status
Cultivate funding from federal agency	National Science Foundation	Yue (VT) and Schroeder (CCAM	$499,784 CCAM Sub-contract: $179,878	Submitted proposal on 02/2020	The proposal, “NRI: FND: Data Sharing and Transfer Training for Sensing-Actuating and Human-Robots Coordinations: Methodology and Open-Source Infrastructure” has been submitted to the NSF NRI 2.0 program. The current status is “pending”. This project focuses on data sharing and transfer training in advanced manufacturing systems.
Cultivate funding from community organization	Clean Energy Smart Manufacturing Innovation Institute (“CESMII”)	Camelio (VT), Yue (VT), Kong (VT), Roberts (CCAM)	$499,784 CCAM Sub-contract: $30,000	Submitted proposal on 03/2020	The proposal, “Building a Trained and Agile Workforce for the Future Intelligent Factory” is pending. This project focuses on building a trained and agile workforce for smart manufacturing through competency-based learning modules.
Cultivate funding from federal agency	National Science Foundation	Yue (VT), Fang (NCSU), Vaziri Sereshk (CCAM), Xie (VT)	$499,784 CCAM Sub-contract: $80,000	Submitted proposal on 06/2020	The proposal, “FMSG: Self-Calibrated Manufacturing: Methods, Algorithms, and Testing” has been submitted to the NSF FM program. The current status is “pending”. This project focuses on developing self-calibrated manufacturing methods, algorithms and testing prototype.
Cultivate funding from federal agency	National Science Foundation	Yue (VT), Bakker (CCAM), Schroeder (CCAM)	$849,563 CCAM Sub-contract: $302,771	Submitted proposal on 06/2020	The proposal, “Collaborative Research: CPS: Medium: Tensor-Enabled Correlation” has been submitted to the NSF CPS program. The current status is “pending”. This project focuses on developing data analytics for advanced manufacturing systems.
Cultivate funding from federal agency	National Science Foundation	Yue (VT)	$495,987 ($15,000 for CCAM for manu-facturing day	Submitted proposal on 08/2020	The proposal “CAREER: Towards Quality Improvements in Manufacturing and Health Care: Hierarchical Correlation Analytics for Transfer Learning” has been submitted to the NSF OE program. The current status is "pending". This project focuses on developing quality control technologies for complex systems, especially advanced manufacturing.

Technical Approaches

The objective is to estimate characteristic tool failure modes in machining operations through the use of data signals collected in-situ as well as optical images captured at regular intervals. This project was split into two primary phases of work. The first, undertaken at CCAM, was the development of a design of experiments (DOE) to identify machining operation, material, tooling and types of data signals to be collected. Once the DOE was finalized, CCAM was to collect data in accordance with the DOE, do preliminary cleaning and

processing of the data and transfer that data to Virginia Tech. In the second phase of work, Virginia Tech is to take the data collected at CCAM and develop a framework for integrating and analyzing it in order to build a model for characterizing and predicting the amount of machining tool wear.

Educational Output

The innovation fund has been used to build a trained and agile manufacturing workforce and improve the education at Virginia Tech. It has supported Ph.D. students Tim Oliver Lutz, CheolHei Lee, Yinan Wang, and undergraduate Hana Wilder. The data collected in the design of experiments are used in the ISE 2034 Data Management for Industrial and Systems Engineers (a required course with about 195 students per semester) to enhance the computational data analytics education of manufacturing workforces.

Joint Publications:

[1] Wang, Y., Guo, W., Yue, X., (2020) “CPAC-Conv: CP-Decomposition to Approximately Compress Convolutional Layers in Deep Learning,” under revision, *IISE Transactions*.

[2] Lee, C., Wu, J., Wang, W., Yue, X., (2020) “Neural Network Gaussian Process considering Input Uncertainty for Composite Structures Assembly,” under 2nd Review, *IEEE/ASME Transactions on Mechatronics*. (This paper was selected as one of the finalists of IISE Data Analytics & Information Systems Best Student Paper Award in 2020. The winner will be selected in Nov. 2020.)

[3] Albahar, A., Joshi, K., Yue, X., (2020+) “Image Based Tool Wear Detection for Advanced Machining Process,” working paper.

Presentations:

[1] Lee, C., (2020) “Neural Network Gaussian Process considering Input Uncertainty for Composite Structures Assembly,” IISE Annual Conference.

[2] Yue, X., (2020) “Data Decomposition for Advanced Analytics of Engineering Data,” SES Annual Conference.

[3] Yue, X., (2020) “StressNet: Deep Learning to Predict Stress With Fracture Propagation” ,INFORMS Annual Conference.

Opportunities from the FY2020 CCAM-University Innovation Program

Project

University Collaboration: Virginia Tech

Spatial Mapping for Context-Aware Augmented Reality Applications

Participants

VT: Dr. Joseph L. Gabbard (Industrial & Systems Eng), Kyle Tannous

CCAM: Tim Bakker, Emma Elliott, Kyle Schroeder, Nathan Puryear

Project Description/Technical Approach

Augmented reality (AR) is a promising approach to support improved worker performance in Industry 4.0. This project will provide proof-of-concept of real-time spatial mapping of indoor industrial spaces for adaptive placement of AR graphics. Additionally, the project will develop a classification scheme for placement of AR user interface elements within the scene. The project will also codify a team and identify external funding sources.

Benefits for CCAM Network (OUM and OIM)

If successful, this project will accelerate several new research domains that can benefit from effective AR technology including: AR to facilitate trust and shared-situational awareness in human-robot collaboration, shared AR spaces and annotation for remote assistance, and wearable AR for inspection and maintenance.

Expected Deliverables

- Proof of concept demonstration that maps an indoor environment and places AR content.
- Lessons learned and open research questions related to adaptive AR interfaces that are contextually aware of dynamic environments; a topic of interest to NSF, DoD (e.g., ONR, Man Tech), DHS, and Advanced Robotics for Manufacturing (ARM).
- Publication submitted to one of: IEEE Virtual Reality, IEEE International Symposium on Mixed & Augmented Reality, or IEEE Transactions on Visualization & Computer Graphics.

Required Equipment and Rough Cost Estimates

- POP: July 1, 2019 – June 30, 2020
- Total Budget $70K
- $35,000 VT/$35,000 CCAM
- Required from CCAM: Virtual factory model, CV and robot expertise, access to CCAM space, exemplar AR use case and associated data

Opportunities and Benefits

VT-CCAM: Spatial Mapping for Context-Aware Augmented Reality Applications

Opportunities and Benefits	Agency or Company	Lead(s)	Value ($K)	Action Date	Status
Cultivate funding and collaboration with Advanced Robotics in Manufacturing (ARM) Institute	Virginia Tech ARM	Gabbard Matt Rosenberger	Access to ARM funding	May 2020	Discussed the ARM RFP process and gauged interest in funding Industrial AR projects, which was high. Expect an RFP related to AR in manufacturing during 2021.
Virginia Tech Membership in Advanced Robotics in Manufacturing (ARM) Institute	Virginia Tech ARM	Gabbard Matt Rosenberger	Access to ARM industrial collaborators and funding	May 2020	Exchanged emails regarding the process and costs associated with a Virginia Tech membership in ARM Institute. Next steps are to see if Virginia Tech wishes to join (CCAM is already ARM member).
Increased capabilities at CCAM for attracting new members and member sustainment	Various member companies	Bakke (CCAM) and Gabbard	Undefined	June 2020	The current project has enabled CCAM to upgrade AR model fitting capabilities in support of future industrial AR application development.

Opportunities from the FY2020 CCAM-University Innovation Program

Project

University Collaboration: Virginia Tech

Integrating Advanced Manufacturing Technologies in Undergraduate Education

Participants

VT: Dr. Jaime Camelio (Industrial & Systems Engineering)

Undergraduate Students: Robert Velasco, Connor Spehlmann, Shannon Hicks, Robert Kadlec, Michael Otooni, Eli Socash, and Manav Sheth.

CCAM: Tim Bakker, Emma Elliott, and Andwele Grant.

Project Description/Technical Approach

The goal of the project was to work with a group on undergraduate researchers to develop a series of testbeds in the Virginia Tech Learning Factory that matched CCAM capabilities. The purpose was to start creating capabilities related to the current Industry 4.0 challenges that start building synergies between CCAM and VT research work. Specifically, the project included the development of three use cases: 1) Construction of a Virtual Factory environment, 2) Development of an Automated Tool Wear Measurement System, and 3) Development of a Holistic Operator Movement Monitoring System.

Benefits for CCAM Network (OUM and OIM)

If successful, this project will accelerate the exchange of ideas and students between Virginia Tech and CCAM. These test beds provide the right setting to train students before they transition to work at CCAM as interns or graduate students. In addition, the development of these capabilities using undergraduate students allows the exploration of new research in the technical areas as well as securing funding related to educational opportunities.

Expected Deliverables

- Testbed including the required equipment at Virginia Tech. For the purpose of this project but using additional funding, VT secure a virtual factory infrastructure, a mobile robot (MIR 100), and a collaborative robot (Aubo R5).
- Training of multiple undergraduate students at Virginia Tech that could become eligible to work at CCAM.
- A virtual factory model including the digital factory infrastructure for Virginia Tech Learning Factory.
- Potential ideas for collaboration between CCAM and additional faculty at Virginia Tech.

Required Equipment and Rough Cost Estimates

- POP: July 1, 2019 – June 30, 2020
- Total Budget: $40K
- VT $20K/CCAM $20K

Opportunities from the FY2020 CCAM-University Innovation Program

Project

University Collaboration: University of Virginia

Data Analytics for Understanding and Defining Powder Bed Fusion Processing Parameters

Participants

UVA: Drs. Ji Ma, Prasanna Balachandran (Materials Science & Eng and Mechanical and Aerospace Eng), Jim Fitz-Gerald (Materials Science & Eng), and Rich Martukanitz (Materials Science & Eng)

CCAM: Kyle Snyder

Project Description/Technical Approach

The goal is to address uncertainty in AM machine-to-machine variability by creating a characterization standard, and through integration with data science and machine learning, understand sources of variability and create predictive capabilities for both defect structure and properties employing a unique multi-machine round-robin comparison in collaboration with CCAM and NASA Langley.

Benefits for CCAM Network (OUM and OIM)

The product most greatly benefits CCAM industry members by improving the ease, efficiency, and speed at which AM techniques can be adopted in their production flow. It leverages the core capabilities of the OUMs in basic research while building a bridge to the business case of OIMs.

Expected Deliverables

This project will create the first unambiguous mapping of processing variation in metal additive manufacturing technology.

- Identification of sources of variability through single track experiments
- Creation and validation of a calibration standard
- Immediate pursuit of external funding – 6 opportunities identified

Required Equipment and Rough Cost Estimates

- POP 12 months
- Total budget $167,300
- $77,500 UVA/$89,800 CCAM
- Utilization of EOS M290 LPBF metal printer at CCAM
- CCAM Technical Point of Contact Mr. Kyle Snyder

Opportunities and Benefits

UVA-CCAM: Data Analytics for Understanding and Defining Powder Bed Fusion Processing Parameters

Opportunities and Benefits	Agency or Company	Lead	Value	Action Date	Status
Cultivate funding and collaboration with major medical device manufacturer	Stryker Spine	Ma and Balachandran		Open	Stryker Spine indicated willingness to small projects on machine learning in AM; NDA draft sent from Stryker Spine and submitted to UVA for review in December, 2019. Stryker will also write letters of support for grants and participate in educational programs in AM at UVA.
Support UVA and CCAM special industrial relationships	Rolls-Royce	Ma and Fitz-Gerald		Open	Rob Porter (AM lead RR NA) indicated the data analytic s program would solve serious needs at Rolls. He indicated that he would be interested in funding such a program if results indicate a sufficient advancement in understanding process parameters and consistency. Funding is being curtailed due to Covid-19.
Cultivate funding and collaboration with major materials supplier	Praxair	Snyder (CCAM) and Martukanitz	Donation of $12K and potential CCAM membership	Tele calls: Nov-Mar, 2020 Call in Sep, 2020	Praxair has a potential interest in joining CCAM and developing collaboration with the AM activities at UVA and CCAM. Praxair donated 50% of the cost of specialized powder to conduct this project. Praxair is discussing a continuation of the research.
Cultivate funding and collaboration with major aerospace company	Boeing	Ma and Balachandran		WEBEX: Jan, 2020	Boeing indicated interest in the project and stated that if it provides a sufficient advancement in understanding process parameters and consistency, it would address serious current needs at Boeing. Brandon Wegge plans to visit UVA in 2020.
Response to federal solicitation, DE-FOA-0002173	DOE Basic Science Office	Ma	$300,000	White paper submitted Jan, 2020.	Early Career Program at DOE. Response from white paper resulted in encouragement for submitting full proposal, but decided to wait till next year for more preliminary data.

Opportunities from the FY2020 CCAM-University Innovation Program

Project

University Collaboration: University of Virginia

Development of Integrated Process and Microstructural Models for Laser-Based Powder Bed Fusion

Participants

UVA: Drs. Leonid Zhigilei (Materials Science & Eng), Chris Li (Mechanical and Aerospace Eng), Bi-Cheng Zhou (Materials Science & Eng), Kang Wang (Materials Science & Eng), and Rich Martukanitz (Materials Science & Eng)

CCAM: Dr. Yuri Plotnikov

Project Description/Technical Approach

The goal of the proposed effort is to begin development of advanced capabilities for predictive multiscale computational modeling capable of revealing the process – microstructure – material properties relationships in additive manufacturing (AM) of metals. The team will use atomistic/mesoscopic/continuum modeling to develop models capable of accurately simulating the complex events and predicting microstructure.

Benefits for CCAM Network (OUM and OIM)

The proposed work will establish UVA and CCAM as experts in this open field, building complimentary capabilities with both organizations. OIMs such as Rolls Royce, Arconic, Oerlikon, Siemens and others have expressed interest in this direction. Also, Federal agencies such as DOE, NSF and various DoD agencies are interested.

Expected Deliverables

Optimize alloying elements and processing parameters that mitigate or eliminate micro-segregation:

- Incorporate complex thermal conditions into in-house LNST code coupled with CALPHAD-type thermodynamic and kinetic databases for AM produced products
- Continuum model predicting crystal defects
- Model validation using experimental methods

Required Equipment and Rough Cost Estimates

- POP 12 months
- Total budget $226,700
- $115,000 UVA/$111,700 CCAM
- Utilization of EOS 290 LPBF metal printer at CCAM
- CCAM Technical Point of Contact Dr. Rich Martukanitz

Opportunities and Benefits

UVA-CCAM: Development of Integrated Process and Microstructural Models for Laser-Based Powder Bed Fusion

Opportunities and Benefits	Agency or Company	Lead	Value	Action Date	Status
Support CCAM Industrial Member for ensuring member sustainment	Amsted Rail	Snyder (CCAM) and Martukanitz	Continued membership	Meetings: Jan-Jun, 2020	Amsted Rail has expressed interest in this project as a Directed Research program. Because their system has just been installed, they would like to wait until later in 2020 for starting a program. A Directed Research program proposal for Amsted is being prepared.
Increased capabilities at CCAM for attracting new members and member sustainment	Various member companies	Plotnikov (CCAM) and Martukanitz	Undefined	Nov, 2019	The current project has enabled CCAM to significantly upgrade in-house thermal sensing, beam monitoring, and process simulation capabilities. These improvements have already been beneficial in supporting member activities. It has also enabled a new research direction at CCAM in Sensor-Driven Adaptive Modeling (see NavalX proposal below).
Response to federal solicitation	ONR Manu-facturing Science	Martukanitz, Plotnikov (CCAM), and Balachandran		Proposal submitted Mar, 2020. Proposal declined.	ONR proposal "Sensor-Driven Adaptive Modeling of the Directed Energy Deposition Process for Assessing and Assuring Process Reliability" submitted. Proposal not awarded.
Response to federal solicitation	NSF Civil, Mech., and Man. Innovation	Zhou, Wang, Martukanitz, and Plotnikov (CCAM)	$250,000	Open BAA	The results in non-equilibrium kinetics developed by Zhou and Wang under this project, combined with adaptive sensing, offers significant opportunities to advanced process reliability. The current NSF BAA under Kershed Cooper is an excellent potential funding source. Proposal being formulated.
Response to a request for CCAM proposal submission	ONR NavalX	Bakker (CCAM), Zimmermann (CCAM), Martukanitz, Plotnikov (CCAM), Young (CCAM)	$5,000,000	Oct, 2020	In response to a request from ONR to CCAM, a white paper is being prepared for a 3-year effort. Although the submission will include a broad range of technologies directed at Development of the Digital Infrastructure for Naval Sustainment, the capabilities developed under the Innovation Program (Sensor-Driven Adaptive Modeling concept) will play an important role in the proposed research.
Development of opportunities for graduate student training and exposure	NSF	Xue	Improved networking opportunities for the University	Submitted	Ms. ZhiJing Xue, who interned at CCAM over the past 2 summers and contributed to this research has submitted a proposal for a prestigious NSF Graduate Fellowship.

Project

University Collaboration: University of Virginia

Air Plasma Spray of Rare Earth Silicate Mixtures for CMAS Resistant Environmental Barrier Coatings

Participants

UVA: Drs. Elizabeth Opila (Materials Science & Eng) and Rebekah Webster (Materials Science & Eng)

CCAM: Ben Zimmerman and Josh Williams

Project Description/Technical Approach

Three compositions of *mixed* ytterbium silicate environmental barrier coating materials will be fabricated via air plasma spray at CCAM to demonstrate ability to process materials with dramatically improved molten calcium magnesium alumino silicate (CMAS) deposit resistance.

Benefits for CCAM Network (OUM and OIM)

The proposed work can demonstrate dramatically improved coating resistance to molten deposits. The proposed work is particularly relevant to CCAM industry members Oerlikon Metco and Rolls Royce. Oerlikon Metco focuses on thermal spray technologies and systems and is a supplier of thermal spray powders.

Expected Deliverables

A demonstration that positive results can be achieved by coatings produced using an industrially relevant process such as APS will open the door to additional funding opportunities, including:

- ONR, Propulsion Materials, $360K total for 3 years, program manager David Shifler
- Air Force Office of Scientific Research, Low Density Materials, $360K total for 3 years, program manager Jamie Tiley
- NSF, Division of Materials Research, Ceramics Program, $360K total for 3 years, program manager Lynnette Madsen

Required Equipment and Rough Cost Estimates

- POP 12 months
- Total budget $106,000
- $57,500 UVA/$48,500 CCAM
- Utilization of APS and steam furnaces at CCAM
- CCAM Technical Point of Contact Dr. Joshua Williams

Opportunities and Benefits

UVA-CCAM: Air Plasma Spray of Rare Earth Silicate Mixtures for CMAS Resistant Environmental Barrier Coatings

Opportunities and Benefits	Agency or Company	Lead	Value	Action Date	Status
Support UVA and CCAM special industrial relationships	Rolls-Royce	Opila and Zimmerman (CCAM)		Open	Coating technologies play a vital role in Rolls Royce products, and improvement of the coating's durability under the conditions evaluated in this project may have broad ramifications to Rolls Royce. The results of this project will be briefed to Rolls Royce.
Federal funding to expand research	ONR Propulsion Materials Program	Opila and Webster	$300,000	Open	The Naval Air System Command has significant interest in the environments that are being evaluated with the advanced coating formulation, and ONR's Propulsion Materials Program could be a likely funding source for expanding this research. Dr. Opila is knowledgeable of the interests of this office and has discussed potential sponsorship with the program manager, David Shifler, but he isn't accepted white papers at this time.
Federal funding to expand research	ARPA-E	Opila and Zimmerman (CCAM)	$2,272,884 CCAM Sub-contract: $303,488	Submitted proposal Sept. 2020	Submitted. a full proposal, "High Entropy Rare-earth Oxide (HERO) Coatings for Refractory Alloys". Sub-contractors include CCAM and Virginia Tech.

Opportunities from the FY2020 CCAM-University Innovation Program

Project: Small Attack Surface and Highly Trusted Devices to Enable the Digital Thread

University Collaboration: Virginia Commonwealth University

Participants

VCU: PI - Dr. Carl Elks, Students – Tamara Pena (MS), Smitha Gautham (PhD)

CCAM: Dr. Tim Bakker, Intern – Scott Bolar (VT)

Project Description/Technical Approach

Given an increasing reliance on digitally connected automation products, advanced manufacturing is an industry that is vulnerable to cyber risk. In 2018, the manufacturing, logistics sector lost an estimated $350M due to cyber-attack disruptions – a 40% increase from 2015 [Deloitte reference]. The purpose of this project was to develop cost effective, enabling technology for secure, safe and trusted automation that can become “roots of trust” for advanced manufacturing applications. This effort builds upon the VCU SymPLe project which concerns the technical realization of verifiable, cost effective and secure platforms for safety critical applications.

Benefits for CCAM Network (OUM and OIM)

The technical innovations developed under this research greatly benefits CCAM industry members by establishing the viability and technical basis for highly secure automation based on the Simplex architecture concept. The development of an open-source highly trusted controller platform can be used as a fundamental building block for realizing secure manufacturing in the context of industry 4.0 standard.

Expected Deliverables

- Development of the Secure Simplex Architecture, laboratory testbed for conducting studies.
- Develop models, prototypes, simulations, and data to fully support next level funding strategies for VCU/CCAM partnership.
- The implicit goal is to use the findings from this investigation to develop strong proposals for either federal or industry funding.
- A technical report, models, and data are expected to be baseline deliverables.

Required Equipment and Rough Cost Estimates

- POP 12 months
- Total budget: $85K/year
- $41K VCU / $44K CCAM
- CCAM Technical Point of Contact Dr. Tim Bakker

Opportunities and Benefits

VCU-CCAM: Small Attack Surface and Highly Trusted Devices to Enable the Digital Thread

Opportunities and Benefits	Agency or Company	Lead	Value ($K)	Action Date	Status
Cultivate funding and collaboration with major Industry partner	Electric Power Research Institute	Elks		Ongoing	Electric Power Research Institute has indicated interest in the Simplex concept to compliment the VCU SymPle architecture. EPRI is funding the PI to develop a secure version of SymPLe architecture ($475K) from 2020 to 2022. EPRI is mainly focused on technologies related to power generation and distribution, and not manufacturing. That said, EPRI is willing to be an advocate for connecting to broader audiences.
Support VCU and CCAM special industrial relationships	Siemens	Bakker		Open	
Cultivate funding and collaboration with Federal Agency	NIST	Elks		Several Zoom meetings:11/2020, 2/2020. and 4/2020	For some time, PI has been collaborating with Dr. Richard Kuhn of Computer Security Division at NIST on projects related to SW testing and cyber security. PI has discussed CCAM project with NIST technical staff on several occasions as potential future collaborative work between VCU, CCAM and NIST. COVID-19 has impacted discussions and progress.
Cultivate funding and collaboration with National Labs	Idaho National Lab	Elks		Multiple Zoom meetings: 10/2019 to 6/2020	PI at VCU has been funded by INL to develop secure by design FPGA based architectures to address and mitigate supply chain, cloning, and lifecycle attacks. Part of this funding was focused on investigating Simplex architectures for reversionary control in Nuclear power applications. The findings of this work are expected to be synergistic to CCAM effort allowing more leverage for the investment.
Findings support federal solicitation	NASA	Elks		Prep-proposal submitted June, '20, Full Proposal submitted Oct '20 Not awarded	UVA (Dr. Barry Johnson) has been leading a multi-university proposal effort to gain a NASA University Leadership Initiative (ULI) center designation on safe and secure autonomy for aerospace applications. Part of the work conducted under this CCAM innovation project supported the pre-proposal submission on June 30, 2020.

Opportunities from the FY2020 CCAM-University Innovation Program

Project: Utilization of UAVs in Manufacturing Environments

University Collaboration: Virginia Commonwealth University

Participants

VCU: Dr. Robert Klenke (Electrical and Computer Engineering), Andrew Fabian (Graduate student, ECE), Matthew Gelber (Graduate student, ECE)

CCAM: Dr. Tim Bakker, Mr. David Young

Project Description/Technical Approach

The goal of this project is to investigate the use of Unmanned Aerial Vehicles (UAVs) for various tasks in indoor manufacturing environments. When operating outdoors, UAVs traditionally use the Global Positioning System (GPS) for navigation and determining their position. Indoors, GPS is not available. Additionally, when operating indoors, there is a much greater risk of collision between the UAV and objects in the environment. Thus, for reliable operation of a UAV indoors, an accurate positioning mechanism and obstacle avoidance capability is needed. For this project, VCU researchers are developing the indoor positioning and obstacle avoidance system. The CCAM researchers are developing the sensors and payload for the UAV to perform the manufacturing-related application they have envisioned.

Benefits for CCAM Network (OUM and OIM)

CCAM has member companies that are exploring the use of UAVs in manufacturing applications. In addition, VCU has a sponsored research project with the Electric Power Research Institute (EPRI) for indoor use of UAVs in nuclear power plants and power generation facilities. This project is directly synergistic with those efforts.

Expected Deliverables

At the beginning of the project, the following tasks were identified:

- Identify application(s) with a high return on investment (CCAM)
- Develop system requirements based on application(s) (CCAM, VCU)
    - Required sensors/actuators
    - Characteristics of physical space(s) where application is to be typically applied
    - Required level of navigation/obstacle avoidance
- Develop UAV system for application(s) (VCU)
    - airframe, flight control system
    - navigation system
    - sensor integration
- Test/demonstrate system on target application(s) (VCU, CCAM)
- Develop proposals to fund additional refinement and expansion to new applications (VCU,CCAM)

The following research products were also identified:

- Development of a combined indoor navigation and obstacle avoidance system for indoor UAV applications in manufacturing environments
- Identification of additional areas of technology and methods that can be further developed to increase utility, accuracy, and speed

- o Identification of new application areas that can be implemented to increase efficiency and reduce costs in manufacturing environments

Required Equipment and Rough Cost Estimates

- POP 12 months
- Total budget $100K
- $50K VCU/$50K CCAM
- UAV, Aries Flight Control System, positioning system, Zed camera (VCU)
- CCAM Technical Point of Contact Dr. Tim Bakker

Opportunities and Benefits

VCU-CCAM: Utilization of UAVs in Manufacturing Environments

Opportunities and Benefits	Agency or Company	Lead	Value	Action Date	Status
Commonwealth Research Commercialization Fund - 2019	CIT	Robert Klenke, Tim Bakker (CCAM)		White paper Submitted Fall, 2019 Proposal not encouraged.	White paper submitted, "*Novel Indoor Navigation Solution for Unmanned Aerial Systems",* but not encourage for full proposal submission. Investigate the use of Unmanned Aerial Vehicles (UAVs) for various tasks in indoor manufacturing environments. When operating outdoors, UAVs traditionally use the Global Positioning System (GPS) for navigation and determining their position. For reliable operation of a UAV indoors, an accurate positioning mechanism and obstacle avoidance capability is needed. For this project, VCU researchers are developing the indoor positioning and obstacle avoidance system. The CCAM researchers are developing the sensors and payload for the UAV to perform the manufacturing-related application they have envisioned.
Numerous visual, contact, or environmental testing/inspection applications, parts and personnel tracking	NSF Advanced Manu-facturing Program	Robert Klenke, David Young (CCAM)	Projected $600K over three years	Ongoing; projected Summer 2021	Proposal being formulated
	Advanced Robotics for Manu-facturing	Robert Klenke, David Young (CCAM)	Projected $600K over three years	Ongoing; projected Summer 2021	Proposal being formulated.

Acoustic aircraft leak detection	Airbus	David Young (CCAM), Robert Klenke	Projected $600K over three years	Ongoing; projected Summer 2021	Waiting on completion of application demo but proposal being formulated.
Acoustic or infrared leak detection, tank inspection	Newport News Shipbuilding	David Young (CCAM), Robert Klenke	In discussion	Ongoing; projected Summer 2021	Waiting on completion of application demo but proposal being formulated.
Warehouse inspection, RFID parts and personnel location	Common-wealth Center for Advanced Logistics CCALS	Robert Klenke, David Young (CCAM)	In discussion	Current	Initial discussions

Opportunities from the FY2020 CCAM-University Innovation Program

Project: Knowledge Extraction and Explainable Machine Learning in Factories of the Future

University Collaboration: Virginia Commonwealth University

Participants

VCU: Dr. Milos Manic (Computer Science), Mr. Daniel L. Marino (Ph. D student), Ms. Chathurika S. Wickramasinghe (Ph. D. Student), Mr. Javier Grandio (Ph. D. student), Dr. Afroditi Filippas (CCAM Fellow, Electrical and Computer Engineering)

CCAM: Mr. Kyle Schroeder, Mr. Keith Bourne, Ms. Emma Elliott

Project Description/Technical Approach

The goal is to study the use of Machine Learning (ML) to extract human performance in a tele-operated robotic environment. The approach will:

- Use multi-criteria performance evaluation to capture knowledge from the manual operators and determine opportunities for automations;
- Develop strategies for evaluating and improving trust of the robotic environment.

Benefits for CCAM Network (OUM and OIM)

This project most greatly benefits CCAM industry members by providing CCAM with the infrastructure and experience to pursue research in the areas of ML, AI, teleoperation and smart factories.

Expected Deliverables

This project will lead to:

- Prototype of an Artificial Intelligence (AI) Augmentation block;
- Software stack used in Augmented AI Teleoperation environment;
- Reconfigurable teleoperation testbed
- Strategic roadmap for improving trust in AI environments.

Required Equipment and Rough Cost Estimates

- POP 12 months
- Total budget $100,000
- $50,000 VCU/$50,000 CCAM
- CCAM Technical Point of Contact: Mr. Kyle Schroeder

Opportunities and Benefits

VCU-CCAM: Knowledge Extraction and Explainable Machine Learning in Factories of the Future

Opportunities and Benefits	Agency or Company	Lead	Value	Action Date	Status
Cybersecurity Manufacturing Innovation Institute (CyManII)	DOE	National Laboratories and US Universities	$70M	FY21-F25 (5yr)	Awarded; VCU lead Prof. Milos Manic; The official announcement of this award, which is a large-scale collaboration among National Laboratories and Universities, will be made in the beginning of October, 2020. The action dates are FY21-25. Professor Manic will work with CCAM scientists and engineers to identify synergistic opportunities for their engagement in this important initiative.
NSF review panel on Future Manufacturing	NSF	NSF	Valuable experience towards further submissions	July 27-28	Prof. Milos Manic selected as (review panelist); The value is in expert recognition & valuable experience, necessary for successful pursuit of NSF CfPs on manufacturing
IEEE research paper[1], accepted and presented at IEEE HIS 2020 Conference	IEEE HSI 2020	VCU	Academic	June 2020	Presented June 2020
Future Manufacturing (FM)	NSF	VCU & CCAM	~$300,000-$450,000	June 2021	Potential opportunity for CCAM involvement

[1] D. Marino, J. Grandio, C. Wickramasinghe, K. Schroeder, K. Bourne, A V. Filippas, M. Manic, "AI Augmentation for Trustworthy AI: Augmented Robot Teleoperation" in Proc. 13th International Conference on Human System Interaction, IEEE HSI 2020, Tokyo, Japan, June 6-8. 2020.

Opportunities from the FY2020 CCAM-University Innovation Program

Project

University Collaboration: Old Dominion University

Human-Machine Accessible Interfaces for Intelligent Factory

Participants

ODU: Hector M. Garcia (Virginia Modeling Analysis and Simulation Center), Dr. Krzysztof Rechowicz (Virginia Modeling Analysis and Simulation Center), Dr. Eric Weisel (Virginia Modeling Analysis and Simulation Center)

CCAM: Tim Bakker, Emma Elliot, Richard Blanchette

Project Description/Technical Approach

The project's objectives are (1) a set of requirements driving the development of a system design resulting in (2) a user experience design (3) integrated with the CCAM Intelligent Factory. Results and information generated throughout the project's duration will be used in a (4) proposal and (5) publication.

Benefits for CCAM Network (OUM and OIM)

- Access to talented problem-solvers (potential students, interns, employees) who are not part of the workforce due to the lack of proper interfaces.
- By embracing "Accessibility By Design", CCAM joins such tech leaders as Microsoft, Google enabling opportunity to partner with them.
- New collaborations (human factors, UX), funding opportunities, and applications of AR and VR as assistive technology.

The proposed work will establish VMASC and CCAM as experts in this open field, exploring the integration of an Inclusive Framework for Industry 4.0. The use of this framework aims to mitigate business risk and offer a competitive advantage by using the framework for including people with different levels of knowledge and abilities to offset the aging population and shifting workforce in the manufacturing industry. Inclusion and accessibility are part of NSF 10 Big Ideas, *Future of Work at the HTF* and *INCLUDES*. NSF EAGER, AFMA, CMMI, and IIS funding opportunity will be targeted. Results from this work will be submitted for publishing at journals such as IEEE Systems, and presented at conferences such as: ACM CHI, ACM SIGACCESS, IEEE Intelligent Environments. OIMs such as Rolls Royce and local school systems have expressed interest in this direction.

Expected Deliverables

- Task 1: Requirements gathering: ODU will work with a community partner and SMEs to identify a population with special sensory needs and elicit requirements for the system.
- Task 2: UX persona development: ODU will create an archetypical user whose goals and characteristics represent the needs of a larger group of users.
- Task 3: System design development: ODU will work on the overall system design including input and output whereas CCAM will provide details regarding Intelligent Factory API.
- Task 4: User eXperience design: ODU will design UX focusing on one user persona by applying the principles of Inclusive and Universal Design.
- Task 5: Proposal development: ODU will lead the proposal development. CCAM will engage as a subcontractor and provide required sections of the proposal.

Required Equipment and Rough Cost Estimates

- POP 3/4/20 – 6/30/20
- Total budget $100,000
- $50K ODU/$50K CCAM
- Utilization of CNC at CCAM, Integration of eFlex for Inclusive Framework
- CCAM Technical Point of Contact: Richard Blanchette

Opportunities and Benefits

ODU-CCAM: Human-Machine Accessible Interfaces for Intelligent Factory

Opportunities and Benefits	Agency or Company	Lead	Value	Action Date	Status
Build relationships with small businesses working with populations of different abilities	Kallobe LLC	Randell Willoughby	Undefined	Collabo-ration from 3/4/20 – 6/30/20	Randell Willoughby is a small business owner that works with people of different abilities and integrates inclusive frameworks to design workflows to enable competitive productivity within a standard assembly / packing / manufacturing job. Our collaboration helped develop an inclusive framework workflow for a CNC task for the CCAM project. We are currently working on extending this framework.
Build relationships with small businesses working with populations of different abilities	Versability Resources	Withney C. Lester	Undefined	Communi-cations from March – June	Versability Resources is a business that provides jobs for people with disabilities. Our current collaborations have provided access to their facilities and personnel to gather requirements in the creation of Personas used in the designed inclusive framework. We are working on future collaborations which include Industry 4.0 at their facilities.
Add Inclusive capabilities at CCAM shop floor	CCAM	Richard Blanchette	$20,000	Collabor-ation March - July	The current project has enabled CCAM to integrate an eFlex system to add the designed inclusive framework to an existing CNC machine and machining task. This integration looks to illustrate the benefits of the inclusive framework in Industry 4.0 to CCAM members. Working on finalizing this integration for testing.
NSF INCLUDES Alliances Solicitation (NSF 20-569)	NSF	Hector M. Garcia / Jessica Johnson.	Proposal will ask for $350K over 2 years.	Letter of Intent Oct 2020 Full proposal Jan 2021	Working on letter of intent. Proposal will focus on the use of Human-Machine Accessible interfaces as a means to increase the participation and ensuring the contributions of individuals from groups that have been historically underrepresented in the advanced manufacturing industry.

Opportunities from the FY2020 CCAM-University Innovation Program

Project

University Collaboration: Virginia State University

A Deep Learning Based Framework for Automatic Thermal Barrier Coating Microstructure Quantification and Qualification

Participants

VSU Faculty: Drs. Wei-Bang Chen (Department of Engineering and Computer Science), Yongjin Lu (Department of Mathematics and economics), and Xiaoliang Wang (Department of Applied Engineering Technology).

VSU Students: Zanyah Ailsworth (Sophomore Undergraduate Student), and Travis Taylor (Graduate Student)

CCAM: Melissa Tsui, Dr. Huda Al-Ghaib, and Ben Zimmerman

Project Description/Technical Approach

Thermal spray is an important manufacturing technique to create a Thermal Barrier Coating (TBC) which not only provides thermal insulation, but also protects the surface from wear, erosion, oxidation, sulfidation, and hot corrosion. This technique has been widely used in various industries ranging from aerospace to biomedical. This proposal aims to develop a novel fully automated computer vision and deep learning-based framework to measure total porosity and distinguish globular (pores) and interlamellar (cracks) using the images of the top coat layer captured from light microscope. By classifying these two microstructures, one could in turn calculate the proportion of globular and interlamellar respectively in the top coat layer and further analyze the coating quality quantitatively.

Benefits for CCAM Network (OUM and OIM)

The project addresses thermal spray which is a commonly and widely used advanced surface engineering technique. The proposed work will benefit members in the CCAM Network to develop an objective approach to accurately measure coating quality using computer vision and deep learning. The proposed project will also develop deep learning, artificial intelligence, and unstructured data analysis capabilities for exploring for exploring not only surface engineering but also other research areas in CCAM Network.

Expected Deliverables

The proposed project will produce a prototype of a fully automated total porosity measure and microstructure classification software in MATLAB. The research outcomes will be presented and published in an IEEE International Conference and could be further extended as a journal paper.

Required Equipment and Rough Cost Estimates

- Period of Project: 12 months
- Total budget $100,000
- $50,000 VSU/$50,000 CCAM
- CCAM produces thermal barrier coating with three types of coating materials. CCAM captures thermal barrier coating images from the samples with confocal microscope.
- VSU team analyze the captured image on a deep learning workstation to develop algorithm and evaluate the performance of the proposed framework.
- CCAM Technical Point of Contact Melissa Tsui, VSU Technical Point of Contact Dr. Wei-Bang Chen

Opportunities and Benefits

VSU-CCAM: A Deep Learning Based Framework for Automatic Thermal Barrier Coating Microstructure Quantification and Qualification

Opportunities and Benefits	Agency or Company	Lead	Value	Action Date	Status
Create journal manuscript	International Journal of Multimedia Data Engineering and Management (IJMDEM)"	Chen	N/A	Sep 2020	The manuscript has been submitted to IJMDEM on Sep. 16. The submitted manuscript is in double-blind review. We have received one reviewer evaluation comments for publication.
Grant proposal	National Science Foundation	Chen	Estimated $400,000 for 3 years	Letter of Intent submitted July ’20. Proposal to be submitted Oct. ‘20	We have submitted Letter of Intent on July 22. We are preparing the proposal to submit toward NSF Solicitation #20542: Historically Black Colleges and Universities - Excellence in Research (HBCU - EiR). The proposal will be submitted by the deadline Oct. 6, 2020. CCAM will be a sub-contractor.

CCAM-ODU MOU

CCAM

SOLVING ADVANCED MANUFACTURING CHALLENGES

December 6, 2019

Eric W. Weisel, Ph.D.
Director of Applied Research
Office of Research
Old Dominion University
4111 Monarch Way
Norfolk, Virginia 23529

Subject: CCAM –University Plan to Implement & Operationalize University Member Engagement

Dear Eric:

This letter will amend the above captioned MOU in order to permit CCAM and Old Dominion University ("ODU") to satisfy the terms and conditions that were established.

- CCAM has elected to waive the requirement for an on-site Research Fellow and will source a pool of research talent and facilities that are physically present at the ODU campus in Norfolk, VA.

- CCAM commits to sending our research staff to ODU. Dr. Weiss has agreed to facilitate these meetings which will commence in January 2020.

- ODU will commit to the recruitment of a GRA to support the research work. CCAM recognizes that this recruitment process may take longer than other CCAM University Members due to our requirement for US citizenship and green card status and the fact that the composition of ODU's graduate students are heavily non-US and mature students pursuing on-line degrees.

CCAM

SOLVING ADVANCED MANUFACTURING CHALLENGES

- ODU will identify, allocate and spend their Innovation Funds by 30th June 2020.

- ODU will sign the letter committing to forgive indebtedness from CCAM consistent with the other four (4) University Members.

I believe that this letter provides a mutually acceptable path forward that addresses the spirit and intent of the CCAM-University Plan to operationalize the Member Agreement.

Regards,

William T. Powers
President and Chief Executive Officer

Accepted: _____
Dr. Eric W. Weisel

Morris Foster
VP for Research