Parallax
ADVANCED RESEARCH

Ohio Federal Research Network
Driving Innovation Through Strategic Partnerships

WELCOME!

Agenda

- **9:00 - 9:15 am** – OFRN/OnRamp Hub: Ohio: Overview by Mark Bartman, Maj Gen (Ret.), VP for Advanced Development, Parallax Advanced Research
- **9:15 - 9:45 am** – Dr. Ahmet Erdemir, Cleveland Clinic
- **9:45 - 10:15 am** – Dr. Charles Cerny, Air Force Research Laboratory
- **10:15 - 10:25 am** - Opportunity Review, Alexzander Myntti, Ohio Aerospace Institute
- **10:25 - 10:30 am** - Wrap-up

Introductions & Thank you

Parallax Team & Event Volunteers

- **Emcee:** Mark Bartman, Maj Gen (Ret.), VP for Advanced Development, Parallax Advanced Research

- **Parallax Team:**
  - Becky Mescher
  - Lauren Jones
  - Jess Pacheco
  - John Jackson

- **Event Speakers:**
  - Dr. Ahmet Erdemir, Associate Staff in the Department of Biomedical Engineering, Chief Scientist of the Cleveland Clinic – IBM Discovery Accelerator, and Interim Director of Office of Research Development, Cleveland Clinic
  - Dr. Charles Cerny, Principal Electronics Engineer, Air Force Research Laboratory

- **Opportunity Review:**
  - Alexzander Myntti, System Engineer, Ohio Aerospace Institute

- **Government partners:** AFRL, NAMRU-D, NASA-GRC, NASIC, Ohio National Guard

OFRN Construct

Ohio Federal Research Network
Driving Innovation Through Strategic Partnerships

NASA Glenn Research Ctr (GRC) Priorities

Air Force Research Lab (AFRL) Priorities

National Air & Space Intelligence Ctr (NASIC) Priorities

State of Ohio

Industry Needs

PARALLAX & The Ohio State University

Naval Medical Research Unit (NAMRU) Priorities

Ohio National Guard Priorities

Executive Review Board

Technical Review Council

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OFRN Program Impact – to date

Ohio Federal Research Network
Driving Innovation Through Strategic Partnerships

22
Universities & colleges engaged

4+1
Government Partners

106
Business partners engaged

1,100+
Indirect jobs created

359
Direct jobs created

13
Spin out companies created

$61.8M
State of Ohio Investment - ODHE

$374+M
Follow-on Funding Awarded

$39M
Cost Share

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DEPARTMENT OF DEFENSE
DEFENSE INNOVATION
UNITED STATES OF AMERICA

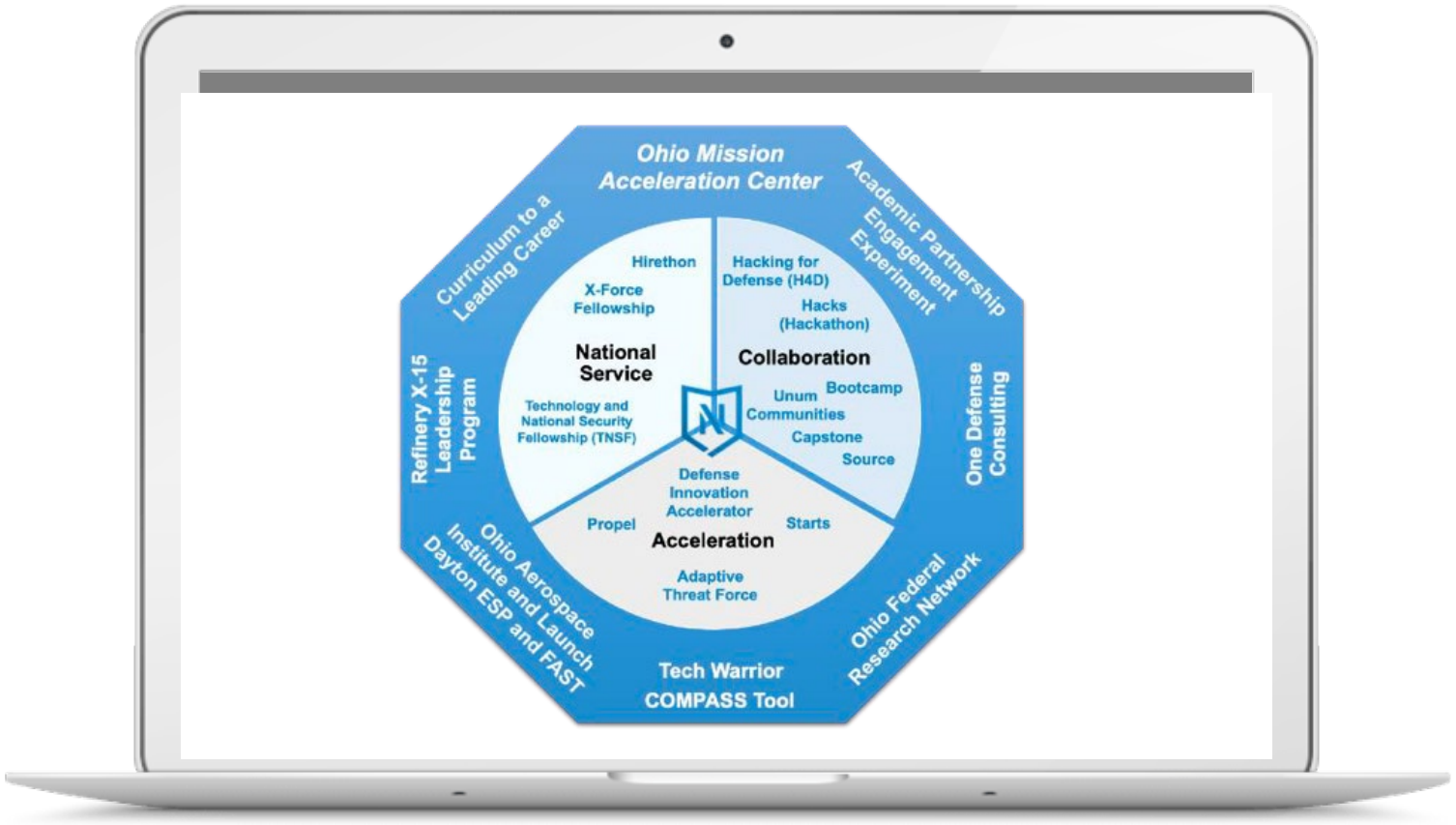
ddc | dayton development coalition

OneDefense

JobsOhio

Defense Innovation Unit (DIU) OnRamp Hub: Ohio

What the OnRamp Hub: Ohio will do:



- ✓ **Front Door** to defense innovation for DoD to Ohio Businesses, academia, state organizations, and non-traditional innovators
- ✓ Parallax Research will coordinate DIU & NSIN programs across the State of Ohio to ensure success
- ✓ Locations across Ohio will provide physical and digital space for entrepreneurs to meet, collaborate and innovate
- ✓ OnRamp Hub will solve DoD problems and transition technologies
- ✓ Provide classified workspace as needed

The OnRamp Hub National Network

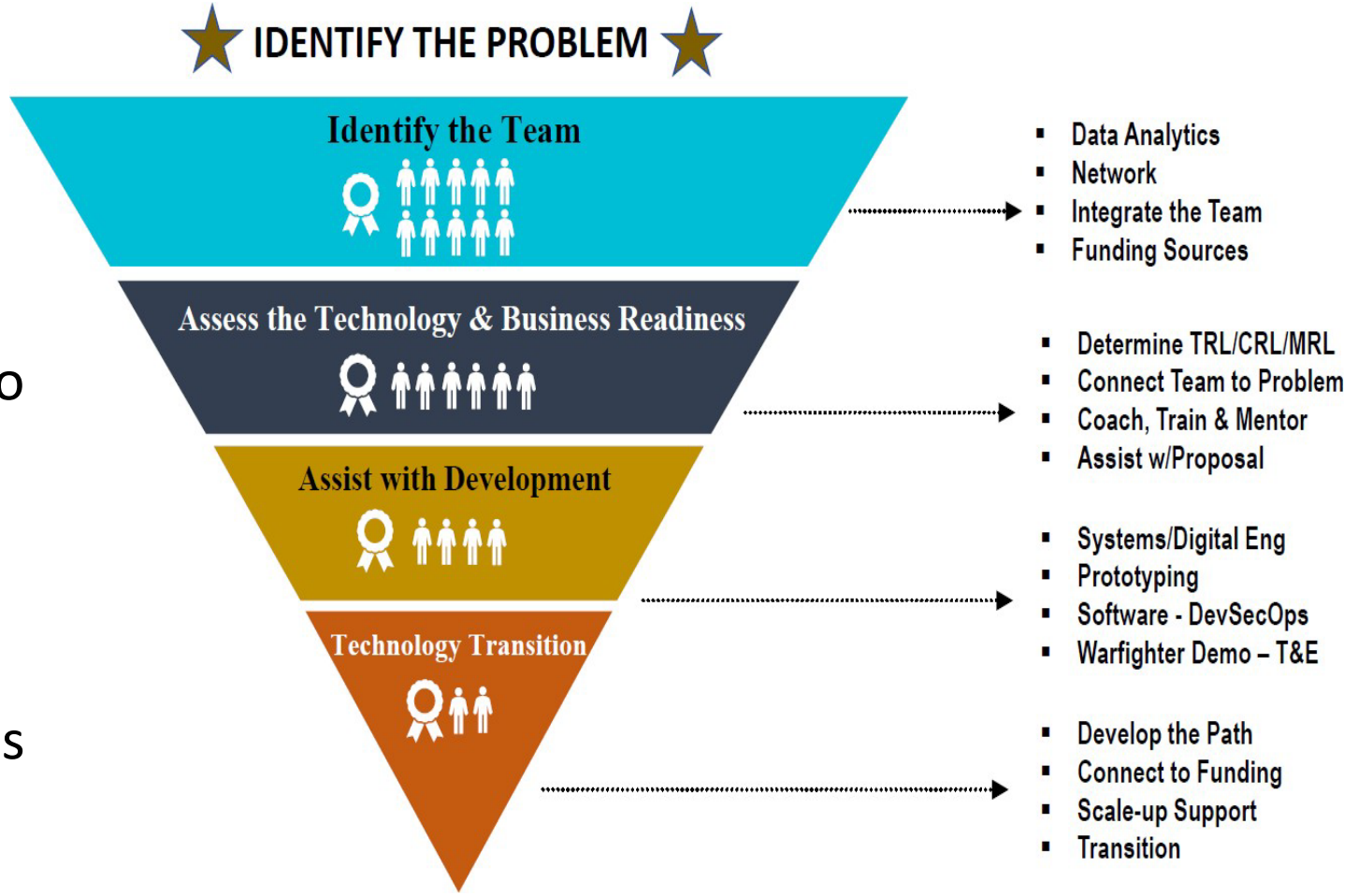
Parallax ADVANCED RESEARCH

What Makes Us Unique

- ✓ **Established existing ecosystems for entrepreneurs and small businesses that have experience working with federal agencies'**
  - **Arizona, Hawaii, Kansas, Ohio & Washington**
- ✓ **Robust networks of angel investors and venture capital**
- ✓ **Extensive State funding to help with startups (ESP, TVSF)**
- ✓ **Follows a systems engineering approach to reduce risk and speed transition**
  - **Ecosystems for prototyping and manufacturing (WBI, CDME, MEPs etc.)**
  - **Test locations – AAM range in Springfield, National Guard locations, Tech Warrior experience**
  - **Airworthiness support from AFLCMC**
  - **Software Factory – Hanger 18 – DevSecOps, Cloud, AoA**

Positioning the Right Solution

The DIU OnRamp Hub: Ohio leverages technology scouting to find the most advanced and promising technologies to meet the DOD's operational demands



Academic Partnership Engagement Experiment

Mission: To connect universities, businesses, and the government together; build collaborations between these sectors; identify their transformational operational defense solutions and capabilities; and advance defense technology transition/transfer and reduce risk for the Department of the Air Force.

Core Competencies:

IDENTIFY collaborators, innovators and technology opportunities using robust data analytics and active connection programs

BUILD & CONNECT a nationwide network of innovators and technologists from universities, small businesses and government

DEVELOP & DEPLOY & DRIVE INNOVATION through targeted education programs providing hands on training to university and small business innovators on how to effectively interface with the DoD

ACCELERATE & DIVERSIFY the transition pipeline via challenge problems, novel and targeted small business and technology transition opportunities with the DoD and its suppliers

APEX

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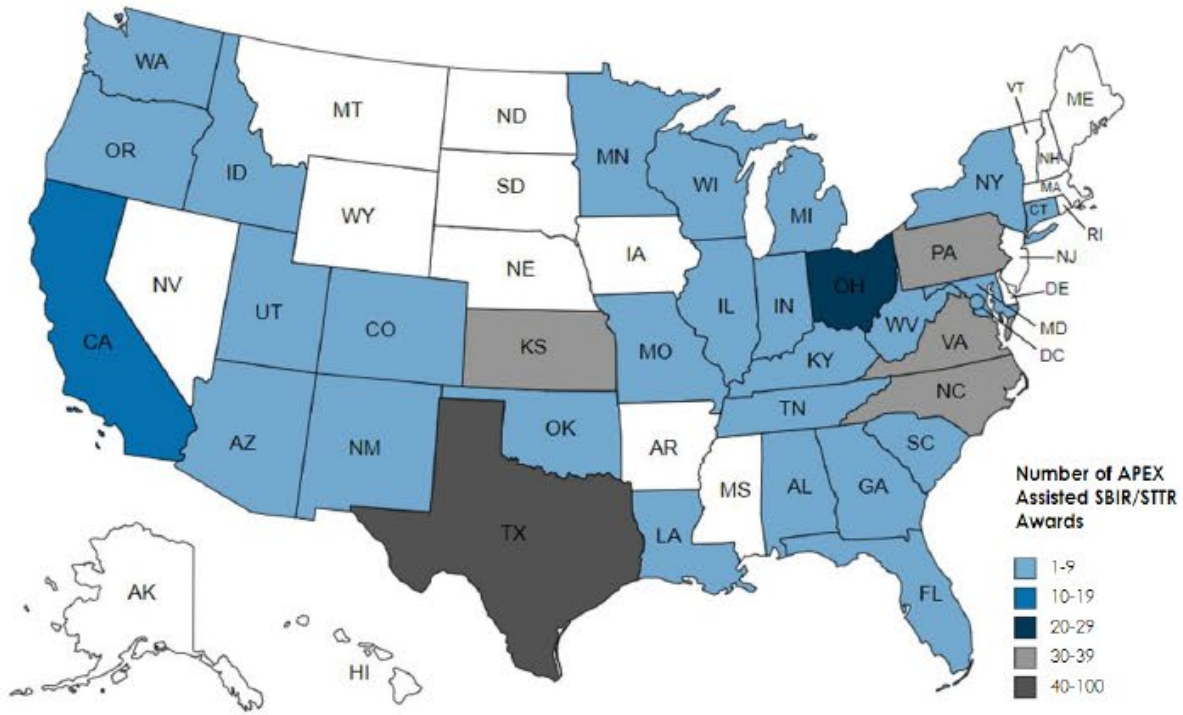
Nationwide Impact:

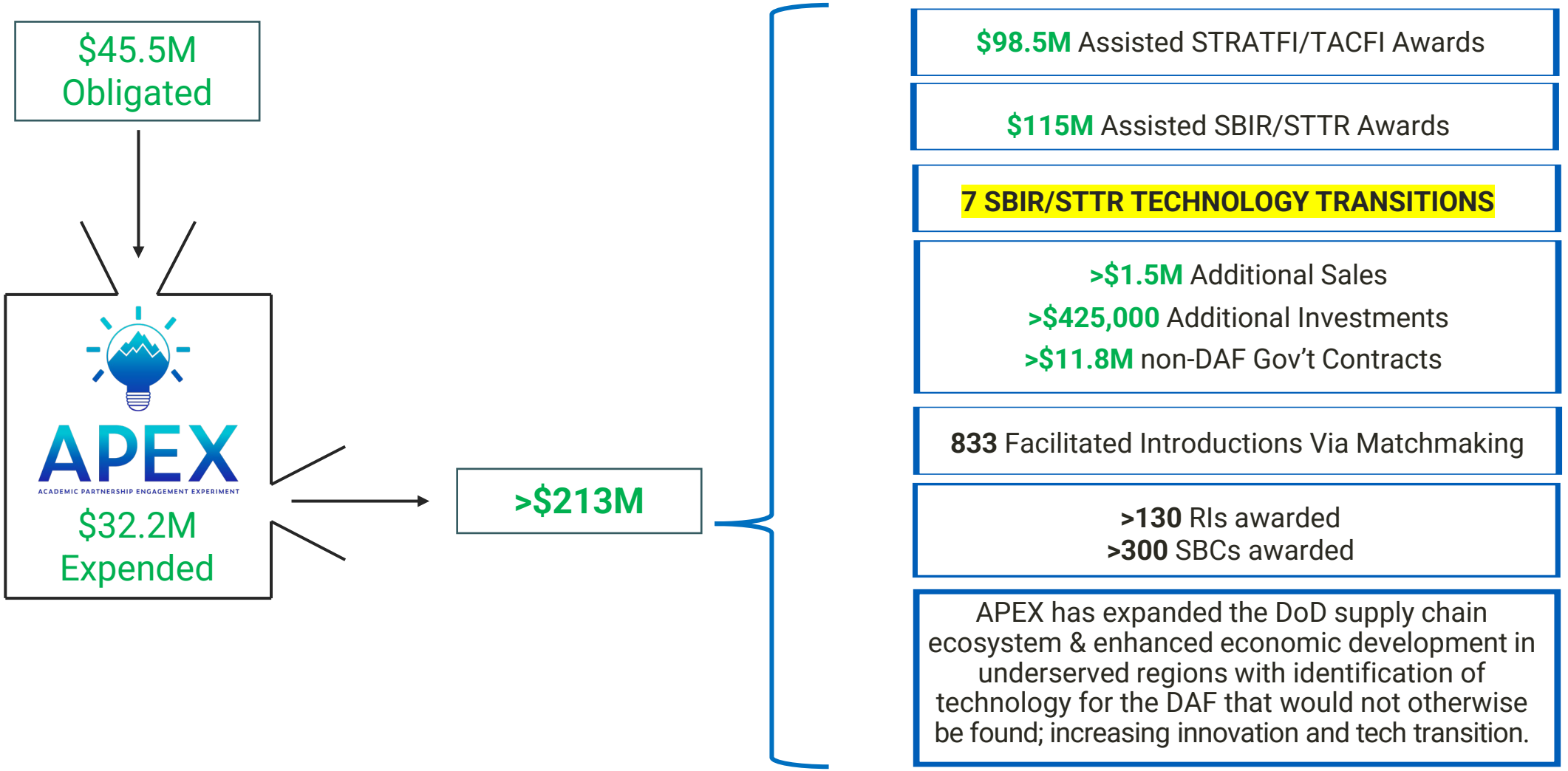
APEX has assisted over 300 small businesses throughout 33 states and over 130 research institutions throughout 26 states with receiving R/R&D funding to bring innovation to the warfighter.



Gov't Return on Investment

To date, the PIA has expended $32.2M of our obligated funds since the inception of the program in 2019.

In this time, the team has achieved some major milestones with benefits to the DAF, academia and industry focused on technology transfer and transition.



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OHIO AEROSPACE INSTITUTE

Thank you

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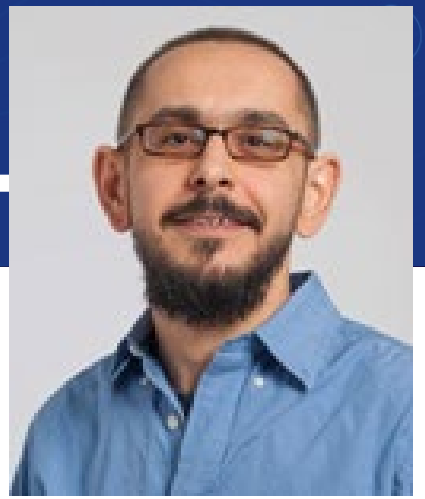
Ohio Federal Research Network
Driving Innovation Through Strategic Partnerships

Dr. Ahmet Erdemir
Cleveland Clinic



Cleveland Clinic IBM Discovery Accelerator

ADOPTING QUANTUM COMPUTING FOR BIOMEDICINE

OFRN Opportunity Day

June 20, 2024

IBM | Cleveland Clinic

Cleveland Clinic IBM Discovery Accelerator

The path forward to transform research through data

Learning from a million patients to better care for each one

Build

Data and bio-specimen estate

- BioRepository
- Digital research infrastructure

Accelerate

Research and innovation

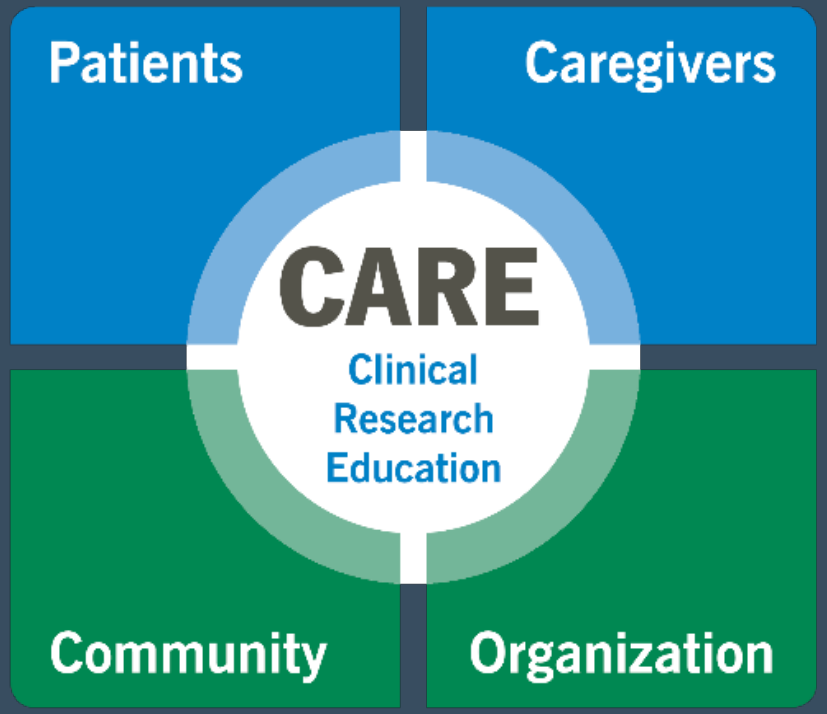
- Data as a service
- Federated governance

Transform

Science, patient care, public policy

- Partnerships
- Learning health system

At 100 years old: Mission focuses on health NOT sickness



CARING FOR LIFE

RESEARCHING FOR HEALTH

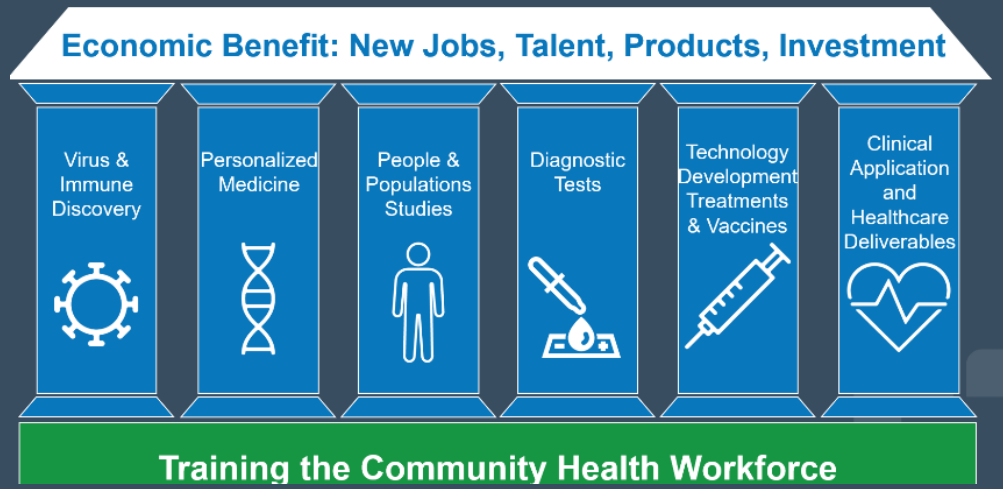
EDUCATING THOSE WHO SERVE

Building the biospecimen and data assets

Cleveland Clinic Bio-Repository

610k bio-specimens since inauguration in October 2021.

Cost of enrollment/collection 5X less than traditional bio-banking approaches.



CC Center for Pathogen Research & Human Health

$500M partnership with State of Ohio, Jobs Ohio to create Cleveland Innovation District.

Doubling research space and exponentially increasing data and computational needs

Critical synergies among research areas and with the community

10- year Strategic Relationship with IBM:

Four programs to accelerate scientific discovery

Research Collaboration and Commitments:

Projects approved by Joint Steering Committee in broad research areas can be pursued with individual Statements of Work

AI and Digital Technologies; High Performance Compute, and Hybrid Cloud Program:

Deploy IBM Research Technologies and license IBM's hybrid cloud

Quantum Program:

Immediate access to IBM's shared Q Systems, first private onsite Quantum system in the US

Education and Outreach Program:

Skills-oriented training and certificate program offerings to faculty, students and researchers

Computational Platforms

High performance computing

Artificial intelligence

Quantum computing

Local Effort in Cleveland

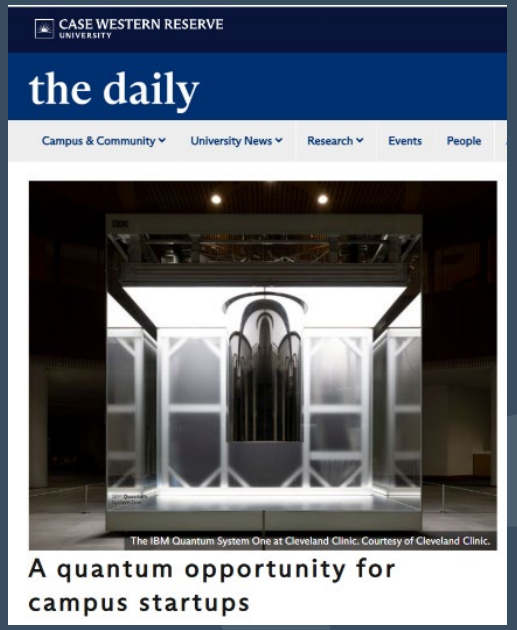
Research
(>40 studies)

Scan to see our projects in quantum computing, digital health, & accelerated discovery

Education
(>2,000 learners)

18 local high school & middle school students attended our summer workshop for students & educators in Summer 2023

Innovation
(3+ startup awards)



The Cleveland Clinic Quantum Innovation Catalyzer Program

Local Effort …for Global Impact

Ecosystem Example Discussions

novo nordisk®

HMRI
Hunter Medical Research Institute

Zambon

SWElife

algorithmiq

UK Science & Innovation Network

YONSEI UNIVERSITY

leap^w

CONNECTED DMV

Policy

U.S. Chamber of Commerce

AEI AMERICAN ENTERPRISE INSTITUTE

act-iac
Accelerating Government

Information Technology Industry Council

Reputation

Quantum computers could solve problems in minutes that would take today's supercomputers millions of years

60 MINUTES Overtime

By Scott Pelley, Aliza Chasan, Denise Schrier Cetta, Katie Brennar
December 3, 2023 / 7:18 PM EST / CBS News

CBS NEWS

NEWSWEEK MAGAZINE

These Are the 10 Best Hospitals in the World

BY NEWSWEEK STAFF ON 02/28/24 AT 5:00 AM EST

2. Cleveland Clinic
Cleveland

More than a century old, the Cleveland Clinic encompasses 77,000 caregivers, 23 hospitals and 275 outpatient facilities in Ohio, Florida, Nevada, Canada, London and the UAE. Consistently ranked #2 on our list of global hospitals since 2019, the ever-expanding innovation hub is known for discovering serotonin, completing the first successful larynx transplant and developing a triple-negative breast cancer vaccine. Researchers from Cleveland Clinic are trailblazers in medical discovery. In collaboration with IBM, they unveiled the first quantum computer dedicated to health care research last year. In January, the team published a study detailing how artificial intelligence models were instrumental in identifying new targets for immunotherapy. ▸ my.clevelandclinic.org

Cleveland Clinic Discovery Accelerator
Eco-System

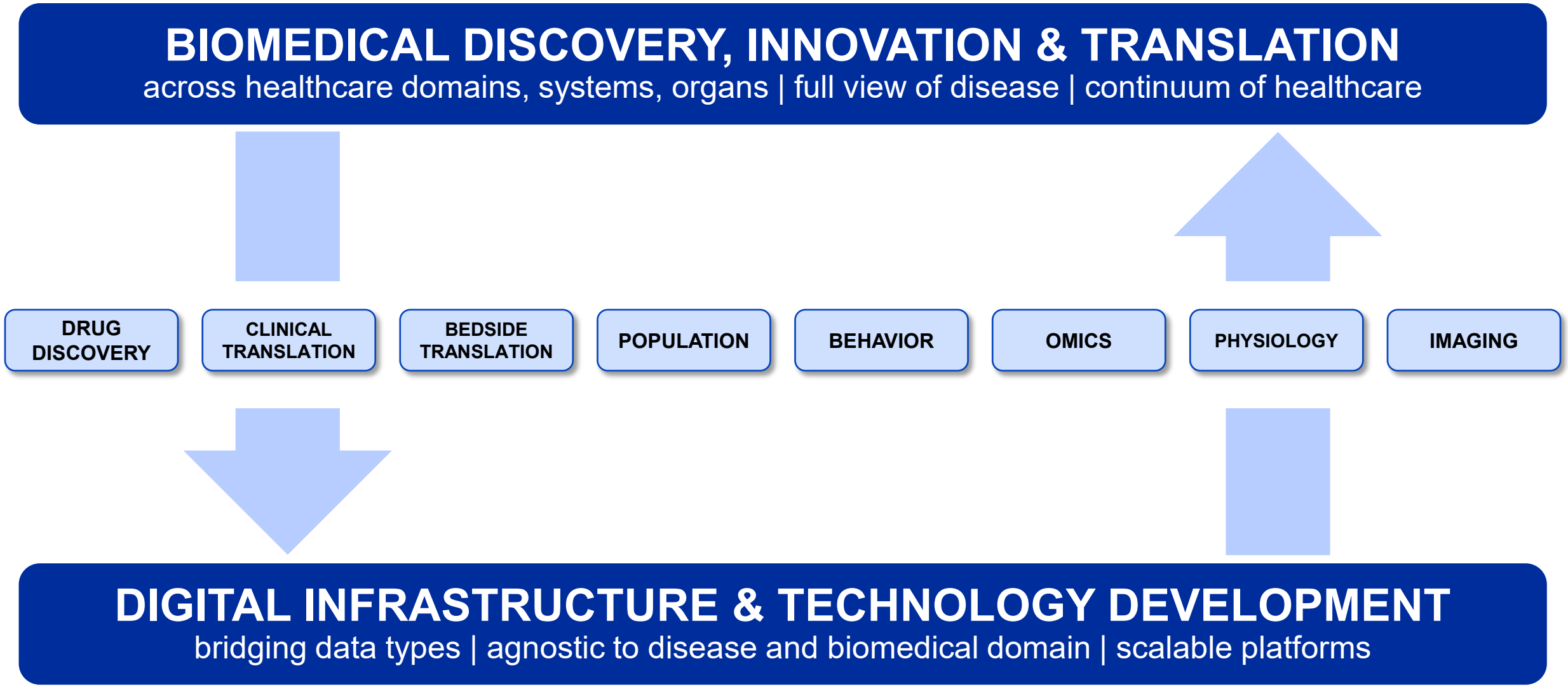
Quantum Computing @ Cleveland Clinic


IBM
IBM Quantum
System One

Our Aspirations for a Quantum Computing Ecosystem

- To create **roadmaps** for evaluation of QC
- To demonstrate quantum **utility** in computational biomedicine
- To build a QC **community**
- To democratize **accessibility** of QC

Our Domain-Agnostic Approach

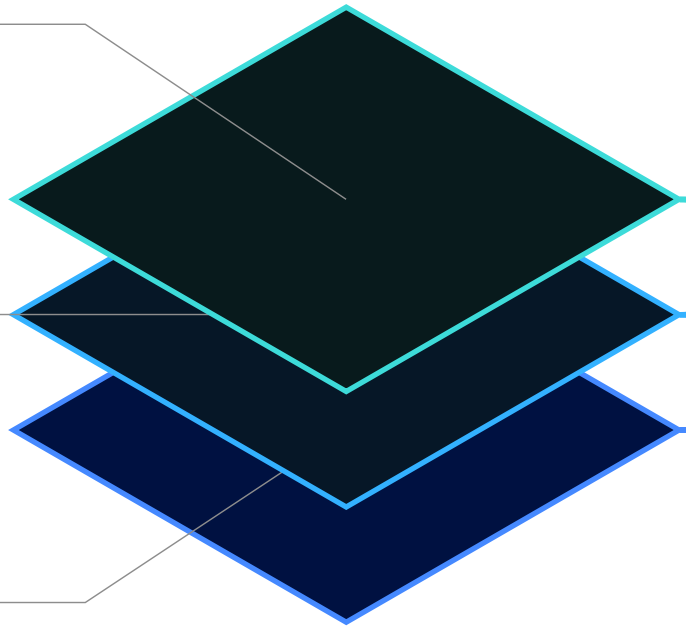


Quantum Computing Use Cases

Simulating nature

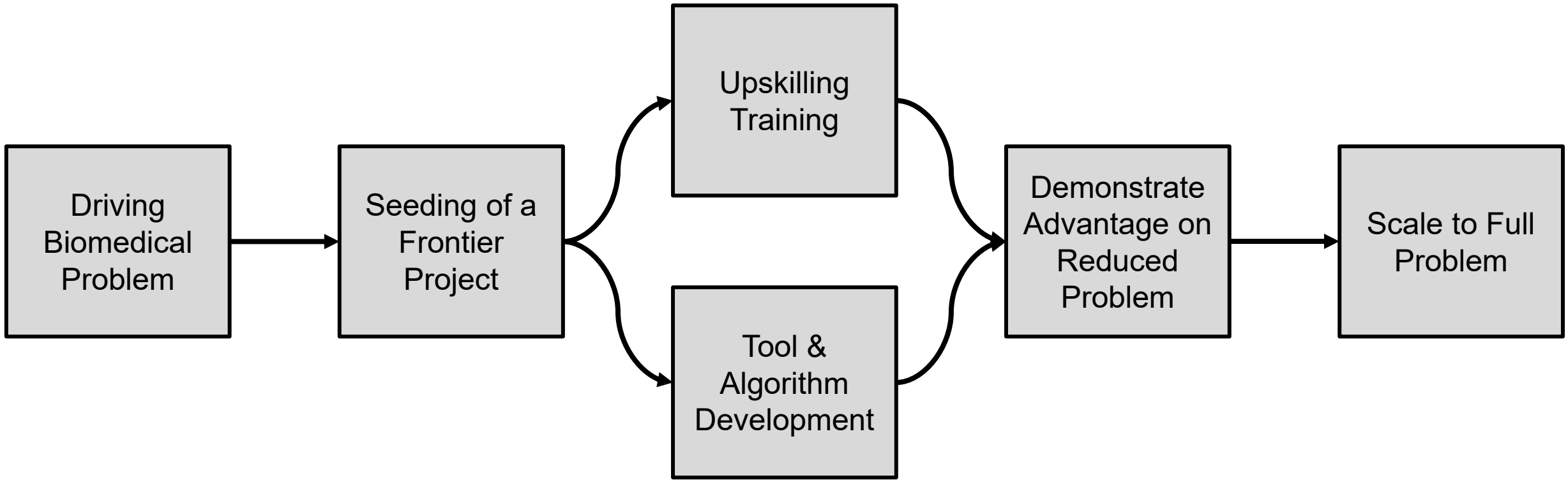
Processing data with complex structure

Search and optimization



1. Drug Discovery
   - ***Molecular Docking***
   - ***De Novo Design***
   - ***Structural Design***
   - ***Immunotherapies***
   - \+ more
2. Precision Medicine
   - ***Disease Risk Prediction***
   - ***Genome assembly***
   - ***Drug Repurposing***
   - \+ more
3. Diagnostics
   - Image Reconstruction
   - ***Early Edge-Case Detection***
   - Microbiome Research
   - \+ more
4. Healthcare Process Optimization
   - Workforce Optimization
   - ***Clinical Trial Site Optimization***
   - Radiology Assignments
   - \+ more
5. Population Heath Management
   - Value-based Care Pricing
   - Population Analysis
   - Disease Spread Simulations
   - \+ more

Our Approach to Use-Inspired Quantum Computing Projects



Wide variety of quantum projects underway – CC & IBM

Name	Status	CC PI	IBM PI
Quantum Simulations of Biochemical Reactions	Planning	Charis Eng, Tim Chan, Kennie Merz	Gavin Jones
CellGPS – Inferring single-cell perturbation responses with quantum contextual optimal transport	Planning	Tyler Alban	Jannis Born
Quantum for Early Lung Cancer Detection	Planning	Peter Mazzone	Laxmi Parida, Hakan Doga, Filippo Utro
Quantum: research collaboration on Quantum Chemistry for Drug Discovery	Active	Jun Qin	Gavin Jones
Quantum Algorithms for Feature Identification and Feature Selection	Active	Xiaojuan Li, Mihriban Karaayvaz, Charis Eng	Omar Shehab, Aritra Bose
Leveraging Quantum Computer for T-Cell Receptor Engineering	Active	Tim Chan	Sara Capponi
Wellcome Leap Q4Bio Program - Quantum Computing for Photon-Drug Interactions in Cancer Prevention and Cancer Treatment	Active	Vijay Krishna	Ivano Tavernelli
Wellcome Leap Q4Bio Program - Protein Conformation Prediction with Quantum Computing	Active	Dan Blankenberg, Jun Qin	Omar Shehab
Investigating Quantum Kernels with EHR Data	Completed	Mina Chung	Omar Shehab
DARPA Quantum Performance Benchmarking	Completed	Dan Blankenberg	Omar Shehab

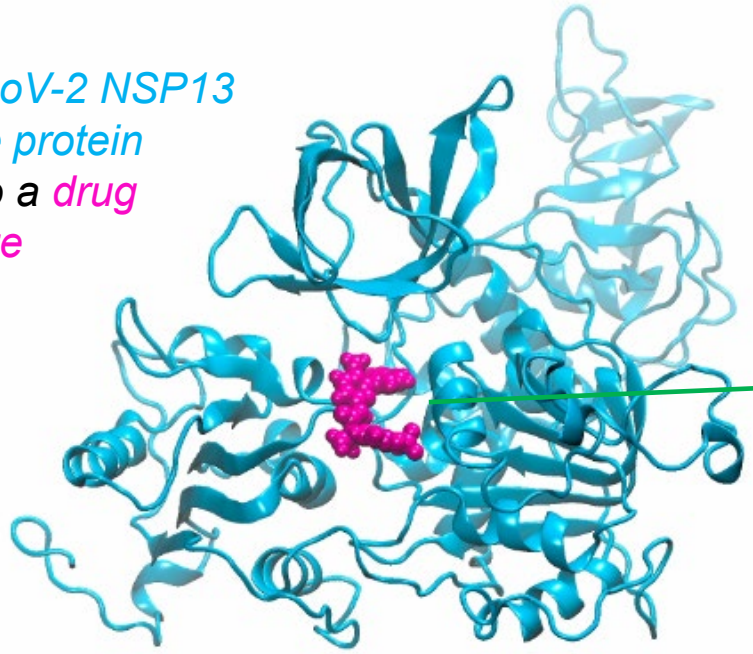
Protein Structure Prediction

Accelerated drug design starts with a target protein structure

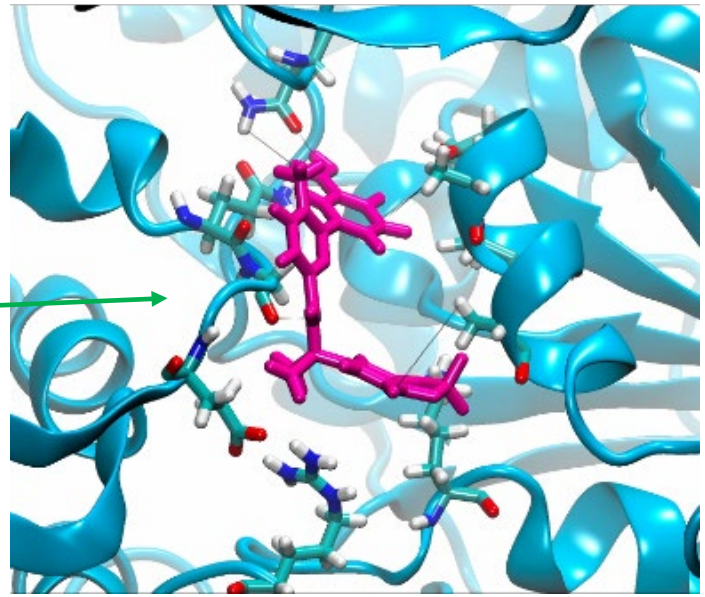
Bryan Raubenolt, PhD

With a known protein structure in hand, we can understand *how* and *why* medicine works → this allows us to make it better!

SARS-CoV-2 NSP13 Helicase protein ***bound to a*** *drug candidate*



A target protein

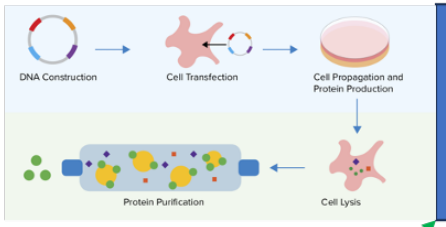


The protein-drug interactions → *why* and *how* the drug works

Raubenolt BA, Islam NN, Summa CM, Rick SW. Molecular dynamics simulations of the flexibility and inhibition of SARS-CoV-2 NSP 13 helicase. J Mol Graph Model. 2022 May;112:108122. doi: 10.1016/j.jmgm.2022.108122.

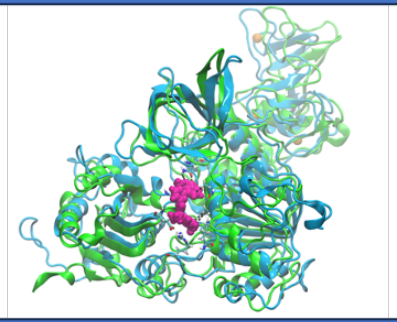
Protein Structure Prediction

So, how is this done in practice?



Experimental protein structure determination
-- Littler over 200K

X-ray crystallography, NMR, CryoEM

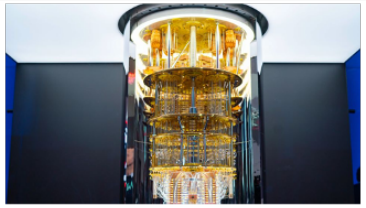


Genome and proteome is sequenced
-- Almost 300 million so far

Every biological function, every component of disease there ever was, is due to a precise 3D shape (or conformation) adopted by proteins. All life as we know it, boils down to this.

In Sillico protein structure prediction

Template based:
Deep learning (AlphaFold2, RoseTTaFold) homology modeling (SWISS-Model, MODELLER) and threading (ITASSER)

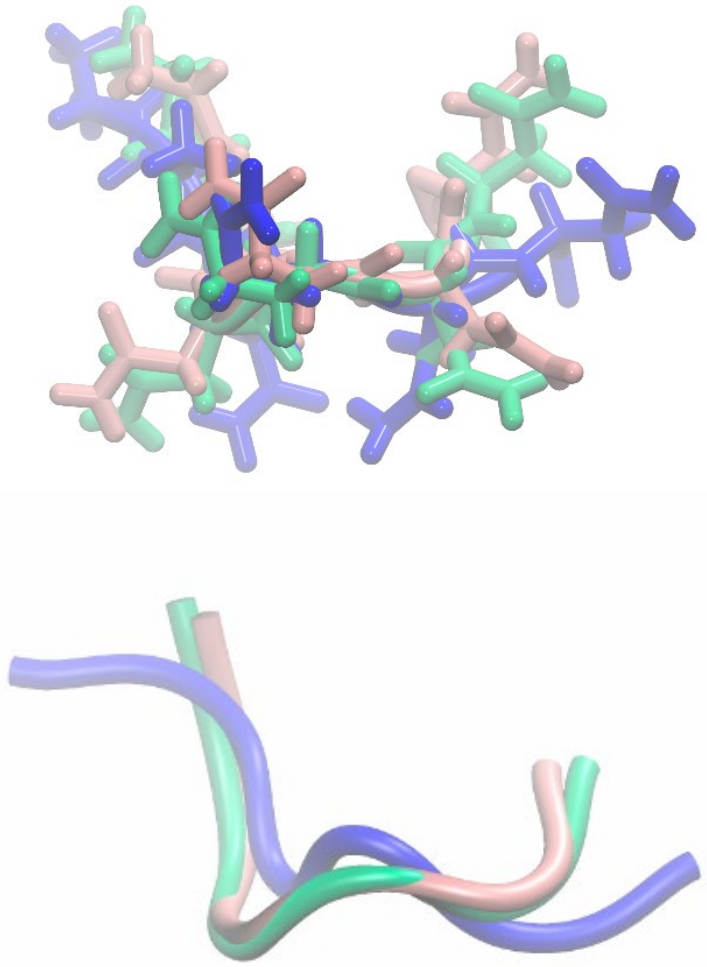


Physics based:
Ab initio, Molecular Dynamics, quantum algorithms??

Protein Structure Prediction

Where could *quantum advantage* potentially come from?

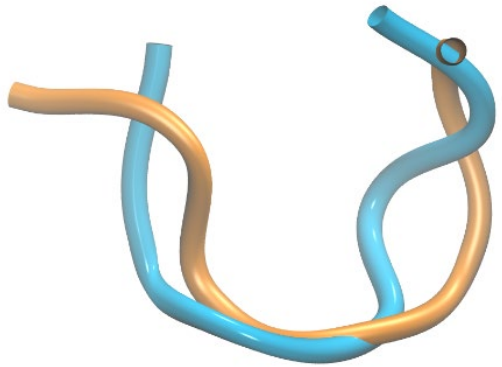
1. Enumeration of the search space/maximum number of conformers per sequence length
    - Can a quantum computer formulate the search space when a classical computer runs out of memory?
2. Optimization of the search space
    - Once enumerated, can a quantum computer traverse the search space and find the best solution, beyond brute force or classical heuristic solvers?
3. Efficient development of quantum chemistry-derived force fields
    - Can we go beyond the system sizes currently limited by classical hardware?



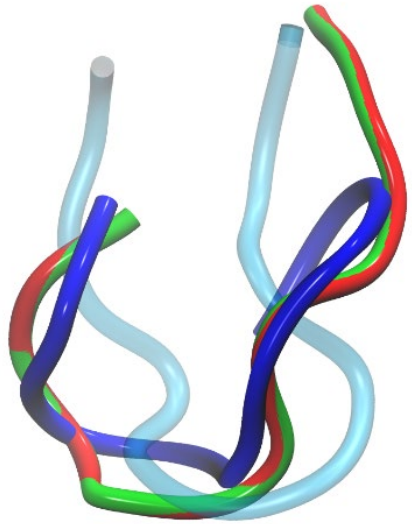
Protein Structure Prediction
Current progress: validation of workflow

- Experimental structures
- Testing algorithm and workflow up to 30 amino acids
- Reasonable accuracy found so far with small peptides
- Next steps: optimization of lattice model and chosen force fields
    - What do we need to reproduce α-helices and β-sheets?

RMSD = 1.781 Å



- Test case: The Zika, Dengue, and West Nile Virus Helicase “P-loop” (7 amino acids)



- Test case: Chignolin (10 amino acids)

Image source: *A perspective on protein structure prediction using quantum computers*, Doga et al. https://arxiv.org/abs/2312.00875 (2023)

Protein Structure Prediction
Current progress: Publication on arXiv

A perspective on protein structure prediction using quantum computers

Hakan Doga[1], Bryan Raubenolt[2], Fabio Cumbo[2], Jayadev Joshi[2], Frank P. DiFilippo[2], Jun Qin[2], Daniel Blankenberg[2], and Omar Shehab[3]

[1]IBM Quantum, Almaden Research Center, San Jose, California 95120, USA
[2]Center for Computational Life Sciences, Lerner Research Institute, The Cleveland Clinic, Cleveland, Ohio 44106, USA
[3]IBM Quantum, IBM Thomas J Watson Research Center, Yorktown Heights, NY 10598, USA

Abstract

Despite the recent advancements by deep learning methods such as AlphaFold2, *in silico* protein structure prediction remains a challenging problem in biomedical research. With the rapid evolution of quantum computing, it is natural to ask whether quantum computers can offer some meaningful benefits for approaching this problem. Yet, identifying specific problem instances amenable to quantum advantage, and estimating quantum resources required are equally challenging tasks. Here, we share our perspective on how to create a framework for systematically selecting protein structure prediction problems that are amenable for quantum advantage, and estimate quantum resources for such problems on a utility-scale quantum computer. As a proof-of-concept, we validate our problem selection framework by accurately predicting the structure of a catalytic loop of the Zika Virus NS3 Helicase, on quantum hardware.

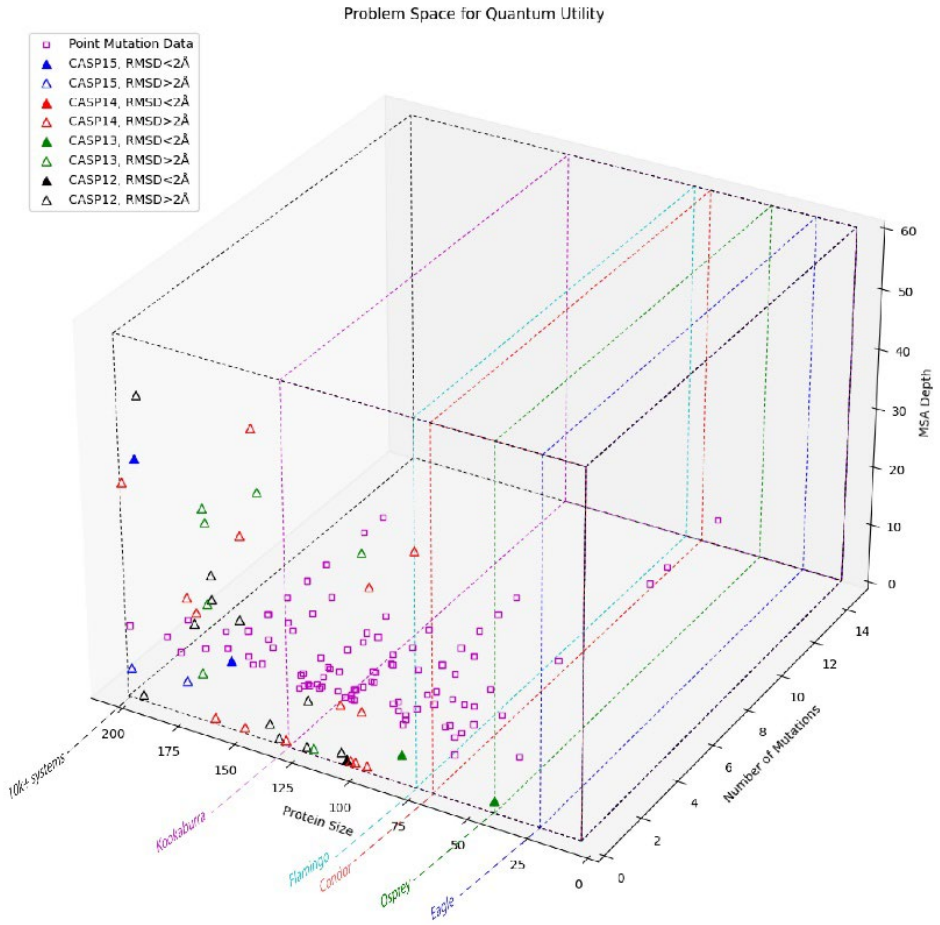


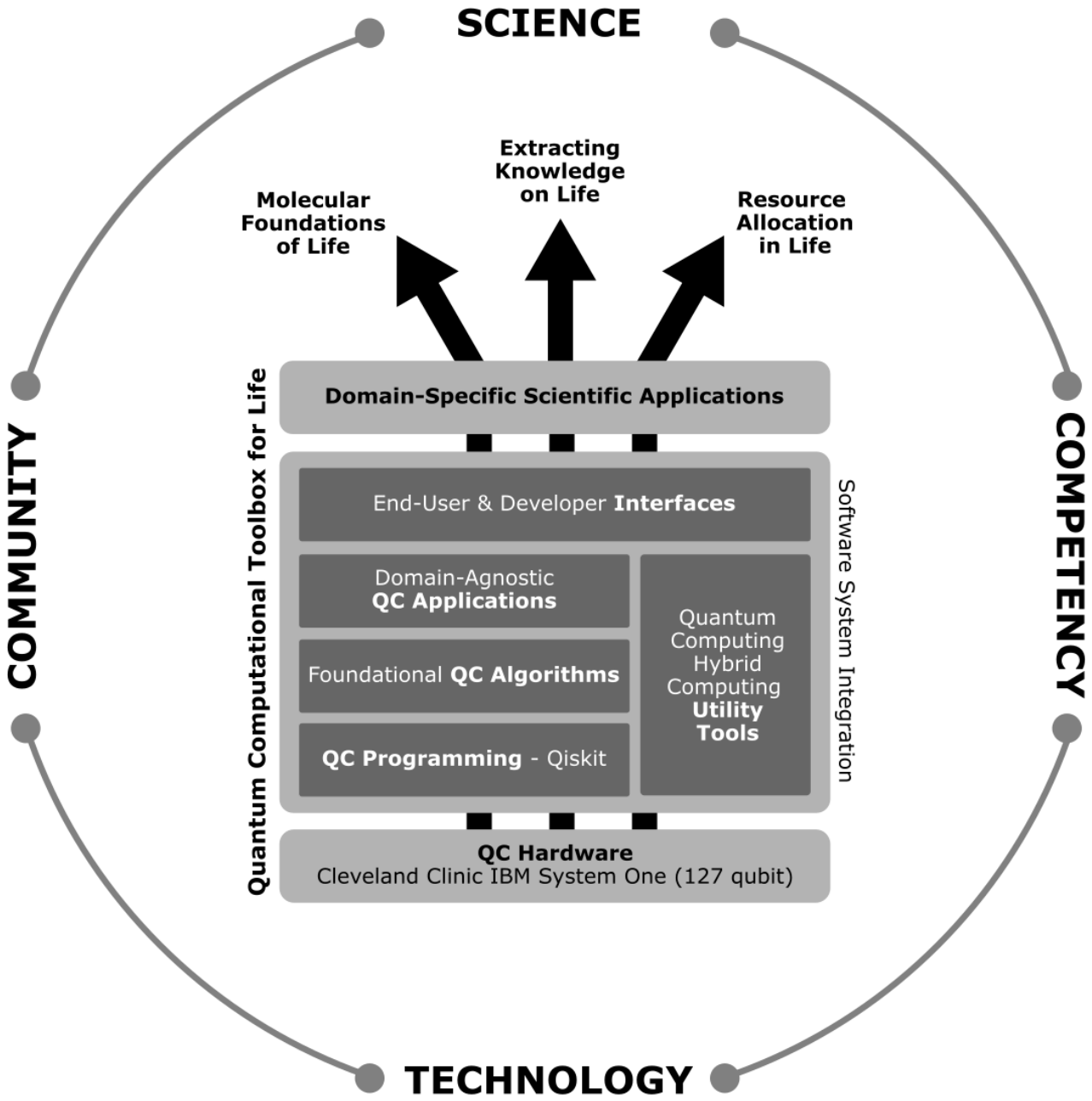
Image source: *A perspective on protein structure prediction using quantum computers*, Doga et al. https://arxiv.org/abs/2312.00875 (2023)

Transferring Experiences To Different Disciplines

Goals

- To map **domain-agnostic** computational science problems and algorithms **to domain-specific** challenges, establishing overlaps across biomedical and aerospace sectors

- To establish a **roadmap** for prioritization, design, and deployment of quantum computing projects for domain-specific demonstrations and utility assessment



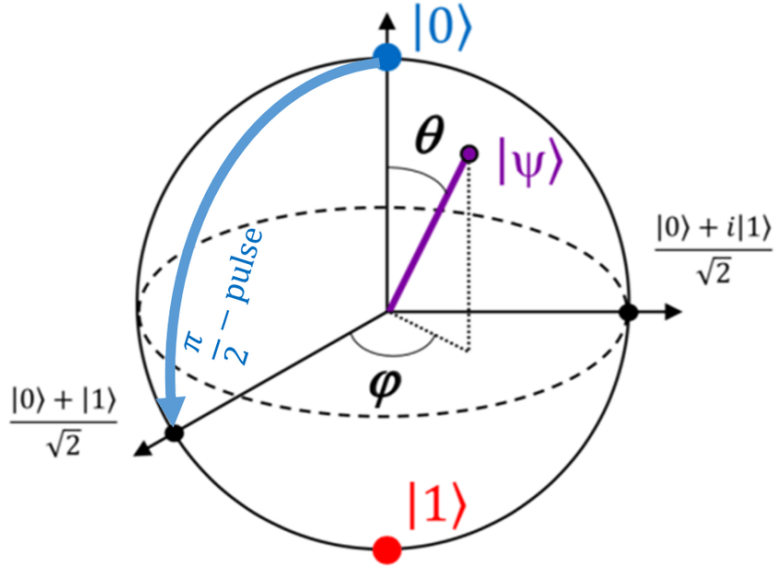
Engaging the Domain Scientists as Stakeholders

Domain scientists are **not** necessarily **computer scientists**.

Domain scientists are highly **driven by domain applications** and solutions.

Challenges for adoption of quantum computing:

- Appreciating what it can do now, and tomorrow
- Devising a pragmatic path to impact domain-specific work
- Learning fundamentals
- Evaluating and then scaling to solve a domain-specific problem



Domain-Specific Problem Space
Biomedicine

DRUG DISCOVERY

- New targets
- New molecular structures
- New biologics
- Repurposing
- Safety and efficacy

CLINICAL TRANSLATION

- Outcome prediction
- Phenotyping
- Disease trajectories
- Operational optimization

BEDSIDE TRANSLATION

- Risk and resource management
- Monitoring
- Sensing and analytics

POPULATION

- Disease spread
- Healthcare access
- Monitoring
- Policy

BEHAVIOR

- Compliance
- Socioeconomics
- Wearables

OMICS

- Biomarkers
- Diagnosis and prognosis
- Phenotyping
- Multiomics
- Accelerated analysis

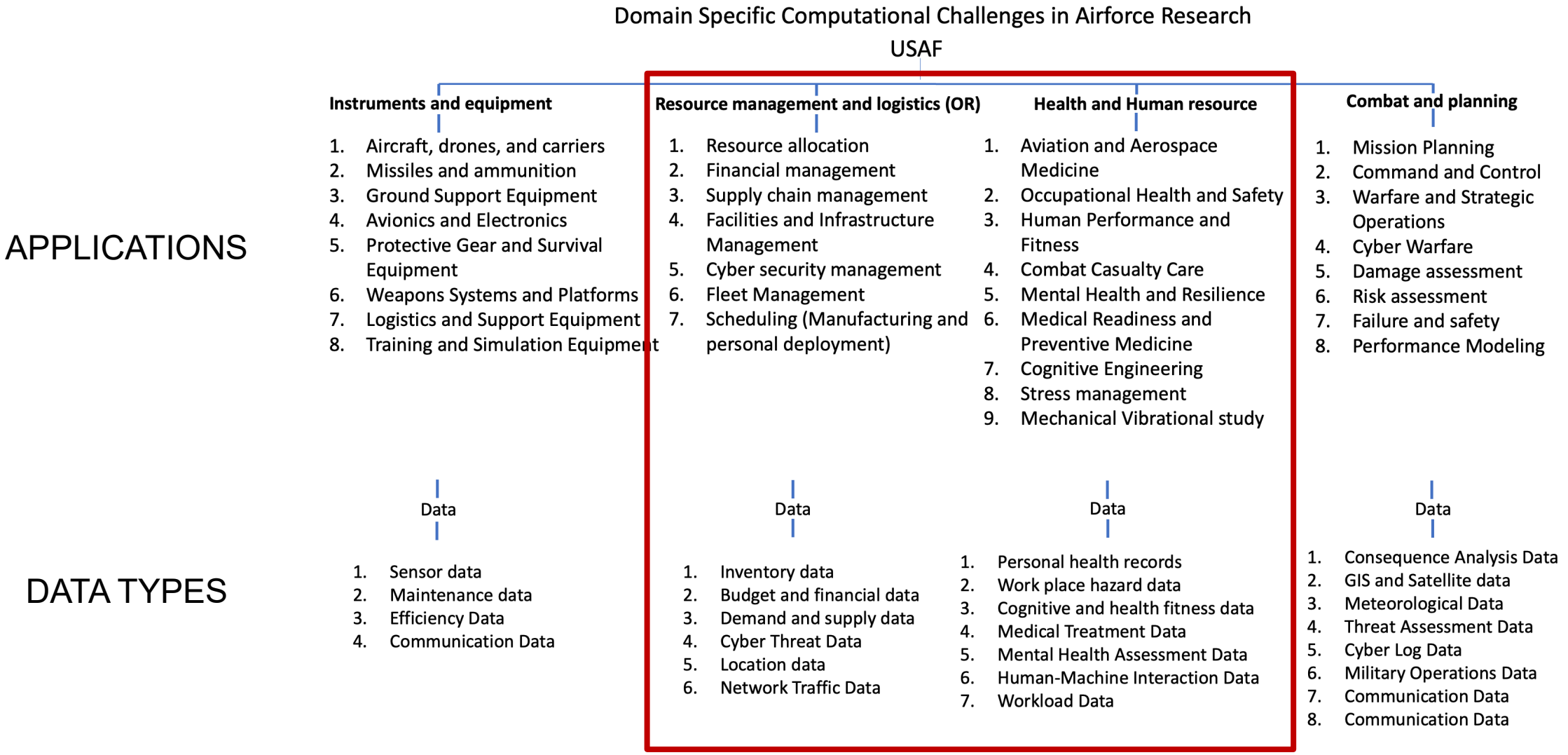
PHYSIOLOGY

- Digital organs
- Disease mechanisms
- Explainable phenotypes
- Wearables
- Signal processing

IMAGING

- Diagnostic markers
- Segmentation
- Stratification
- Monitoring
- Acquisition

Domain-Specific Problem Space
Aerospace



Domain Agnosticism of Computational Challenges

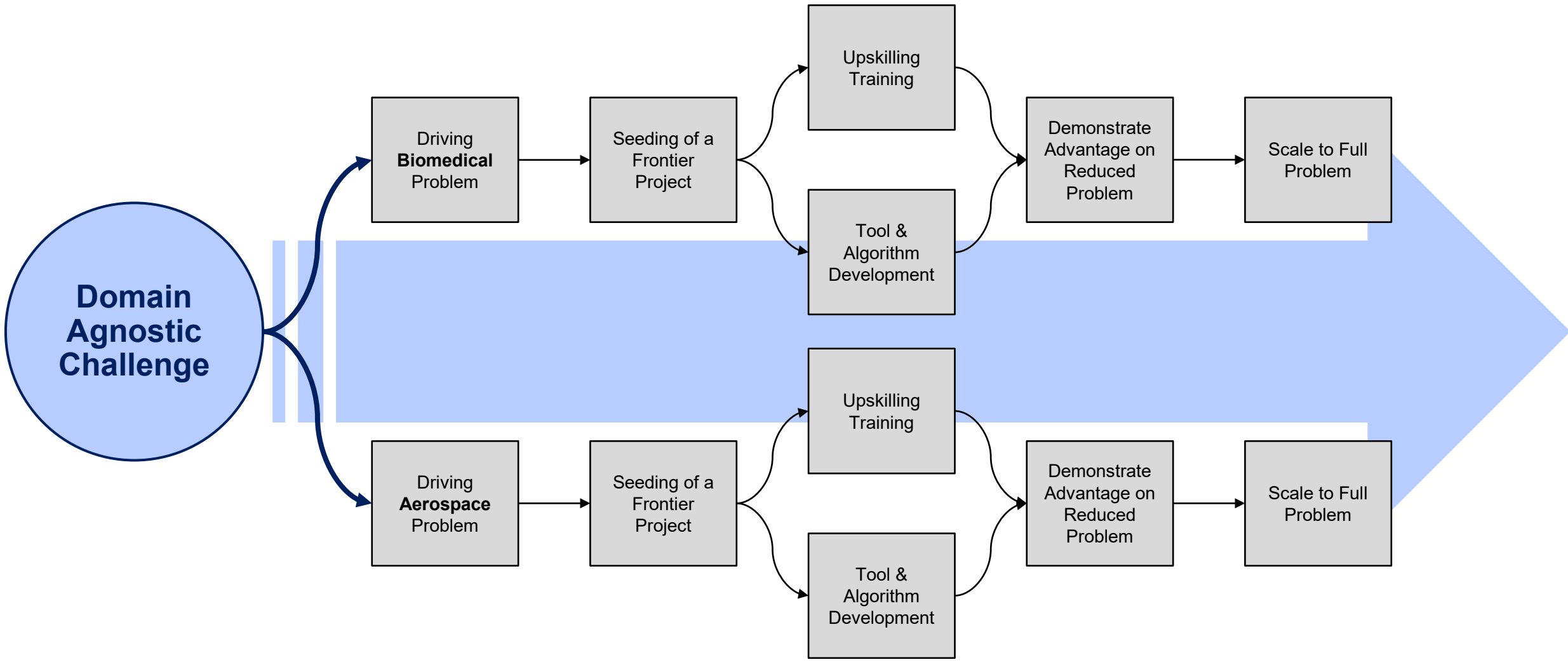
optimization (continuous/discrete, local/global search) - AI/ML - logistics - resource allocation - molecular dynamics - field problems (PDEs) - systems modeling (ODEs) - networks - graph methods - algebraic equations - complex systems - agent-based modeling - computer vision - signal processing - sampling - topology

Leveraging Overlaps Across Domains

Domain-Agnostic Computational Methods for Systematic Customization and Transferrable Utilization Across Domains:

- Solve one challenge; use the experience to **accelerate solutions in other disciplines**
- **Effectively utilize** software and hardware **infrastructure** across diverse disciplines
- **Facilitate workforce mobility** by provide pivoting and cross-domain opportunities
- **Scale** transdisciplinary **education** and upskilling

Adopting Our Approach to Cross-Domain Quantum Computing Projects



Example Use Case
Image Segmentation

Medical Context:

We want to improve medical image segmentation accuracy for improved patient diagnostics.

Aerospace Context:

We want to improve drone image segmentation accuracy for improved military intelligence gathering.

Domain-Agnostic Context:

Object detection in images.

IQFT Inspired Algorithm for Image Segmentation

Algorithm 1 : IQFT-inspired algorithm for RGB image segmentation

Input:

$I = \{ P_m \in \mathbb{R}^3 \}, m = [1, T]$

$\theta_1,\ \theta_2,\ \theta_3\ \in \mathbb{R}$

$W \in \mathbb{C}^{8\times 8}$

Output: $\mathcal{L} = \{l_m \in \mathbb{Z}\}$

for m=1**to** T **do**

1. $\{P_m\} \longleftarrow \{P_m/255\}, \{P_m\} = \{R_m, G_m, B_m\}$
2. $\{\gamma_m, \beta_m, \alpha_m\} \longleftarrow \{R_m \times \theta_1, G_m \times \theta_2, B_m \times\ \theta_3\}$
3. $\{F_m\} = \left\{ \begin{array}{c} 1 \\ e^{i\gamma} \\ e^{i\beta} \\ e^{i(\beta+\gamma)} \\ e^{i\alpha} \\ e^{i(\alpha+\gamma)} \\ e^{i(\alpha+\beta)} \\ e^{i(\alpha+\beta+\gamma)} \end{array} \right\} \longleftarrow \left\{ \begin{array}{c} \gamma_m \\ \beta_m \\ \alpha_m \end{array} \right\}$
4. $\{S_m\} \longleftarrow [abs\,(Dot\ Product\,(F_m, W)\,/8)]^2$
5. $\{l_m\} \longleftarrow \{argmax\{S_m\}\ \}$

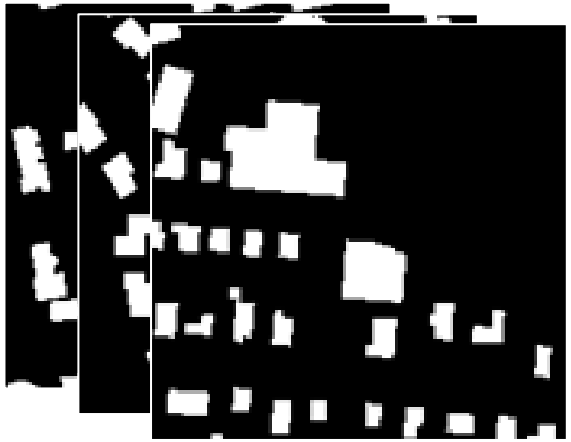
$$\begin{bmatrix} P \\ Q \\ R \\ S \\ T \\ U \\ V \\ W \end{bmatrix} \equiv \frac{1}{8} \times \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & \omega^{-1} & \omega^{-2} & \omega^{-3} & \omega^{-4} & \omega^{-5} & \omega^{-6} & \omega^{-7} \\ 1 & \omega^{-2} & \omega^{-4} & \omega^{-6} & 1 & \omega^{-2} & \omega^{-4} & \omega^{-6} \\ 1 & \omega^{-3} & \omega^{-6} & \omega^{-1} & \omega^{-4} & \omega^{-7} & \omega^{-2} & \omega^{-5} \\ 1 & \omega^{-4} & 1 & \omega^{-4} & 1 & \omega^{-4} & 1 & \omega^{-4} \\ 1 & \omega^{-5} & \omega^{-2} & \omega^{-7} & \omega^{-4} & \omega^{-1} & \omega^{-6} & \omega^{-3} \\ 1 & \omega^{-6} & \omega^{-4} & \omega^{-2} & 1 & \omega^{-6} & \omega^{-4} & \omega^{-2} \\ 1 & \omega^{-7} & \omega^{-6} & \omega^{-5} & \omega^{-4} & \omega^{-3} & \omega^{-2} & \omega^{-1} \end{bmatrix} \begin{bmatrix} 1 \\ e^{i\gamma} \\ e^{i\beta} \\ e^{i(\beta+\gamma)} \\ e^{i\alpha} \\ e^{i(\alpha+\gamma)} \\ e^{i(\alpha+\beta)} \\ e^{i(\alpha+\beta+\gamma)} \end{bmatrix}$$

- 8 state basis vectors: transformation of 3d input [alpha, beta, gamma] to 8d
- Probability of characteristic patterns
- Classification based on highest probability

Akinola, T., Li, X., Wilkins, R., Obiomon, P., & Qian, L. (2023). Inverse Quantum Fourier Transform Inspired Algorithm for Unsupervised Image Segmentation (Version 1). arXiv. https://doi.org/10.48550/ARXIV.2301.04705

Satellite Image Segmentation Buildings

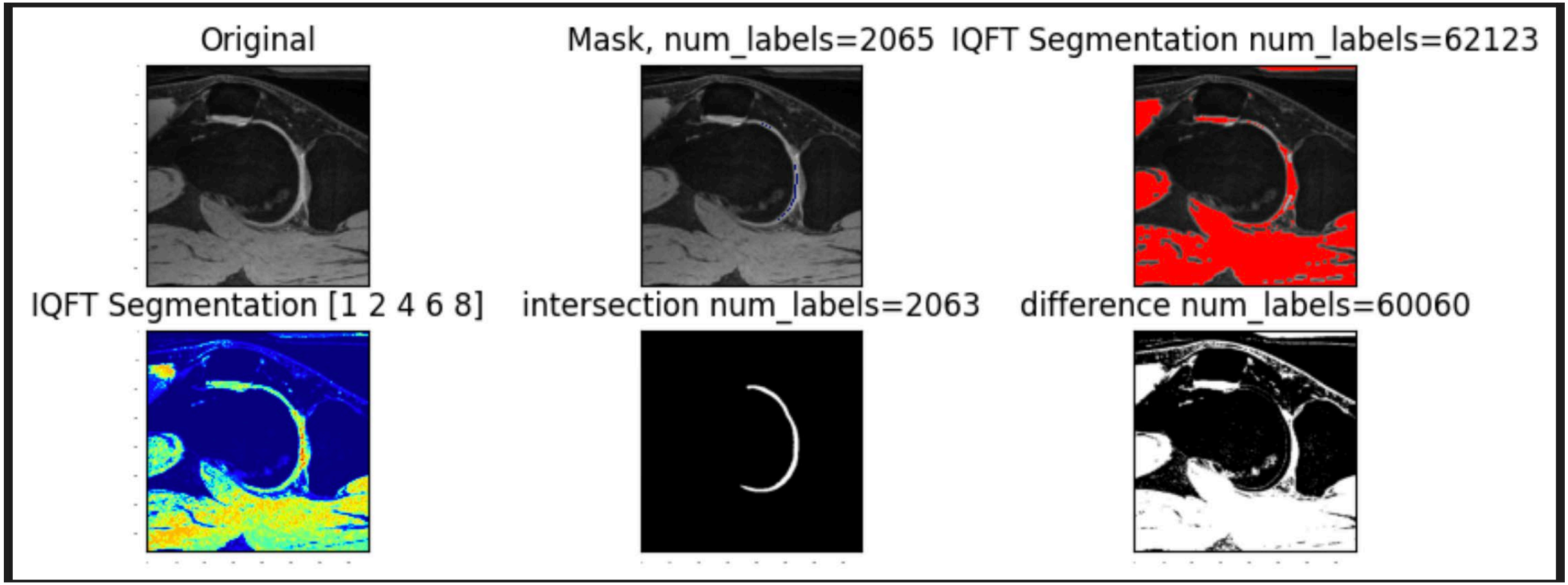
The Massachusetts Building Dataset



Parameter optimization based on training images

Theta 4.0, Dice Score 0.273

MRI Segmentation
Cartilage



Work in progress: Optimization of IQFT parameters

Acknowledgments

FUNDING

Assessment of Quantum Computing Impacts on Air Force Digital Transformation, OAI-DTPP1-24751 (Ohio Aerospace Institute); FA8650-22-2-5720 (US Army Research Office)

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100 YEARS

EST. 1921

THE FUTURE OF HEALTHCARE SINCE 1921

Parallax
ADVANCED RESEARCH

Ohio Federal Research Network
Driving Innovation Through Strategic Partnerships

Dr. Charles Cerny
AFRL

AFRL

RYDBERG ATOM PHOTON INTERLEAVER FOR QUANTUM INFORMATION EXCISION OFRN OPPORTUNITY DAY

DR. CHARLES L A CERNY

AFRL/RYMP

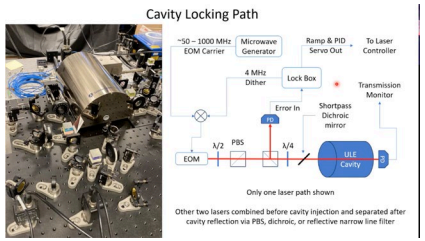
20 JUN 2024

Why Quantum - Mutual Interest

Strength of AF interest/Technical Need

More recently, the Mitchell Institute for Aerospace Studies released a series of policy papers in January 2024 defining “The Quantum Advantage” and referenced from the March 2023 Subcommittee on Quantum Information Science, National Science & Technology Council, that “Quantum sensors, for example, could **offer accuracy, stability, sensitivity, and precision that far exceed those of classical technologies.”** This requires a multi-disciplinary team like the one assembled under the OFRN to create a Quantum Science and Technology industry in the Midwest and a workforce development pipeline.

(Excerpt from AFRL letter of support to OFRN)



Ohio Federal Research Network

Driving Innovation Through Strategic Partnerships

Technical Need

1. The United States and China are both developing quantum computing technology, and some say the two countries are now "nearly equal" in the field. The US has traditionally led the field, but China has made significant progress

Aligns with AF mission and goals

1. Quantum computing can create data and communication systems that are more secure than current computer networks.
2. Supports SECAF Operational Imperative #3: "Achieving Moving Target Engagement at Scale in a Challenging Operational Environment"

Medical

Banking

Military

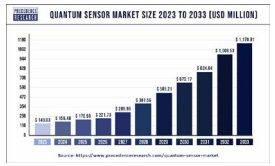
Air Force Mission and Goals/Dual Use

Additionally, USSF applications for communications and navigation could be greatly improved with Quantum Sensing. From a commercial application, Quantum Sensing has the potential to improve security in business transactions and increase the sensitivity of medical scanning equipment. The **AFRL Small Business Office along with AFWERX will be instrumental in tech transfer to DoD customers. This transition path is codified through the Under Secretary of Defense for Research and Engineering OSD Transitions SBIR Technology (OTST) program which has identified Quantum Science as one of their 14 Critical Priority Technical Areas. The result is an increase private sector commercialization of innovations derived from Federal R&D, thereby increasing competition, productivity and economic growth, establishing a proactive and predictive approach to the development of mission critical technologies.**

Why Quantum - Transition

Addresses scientific/technical transition

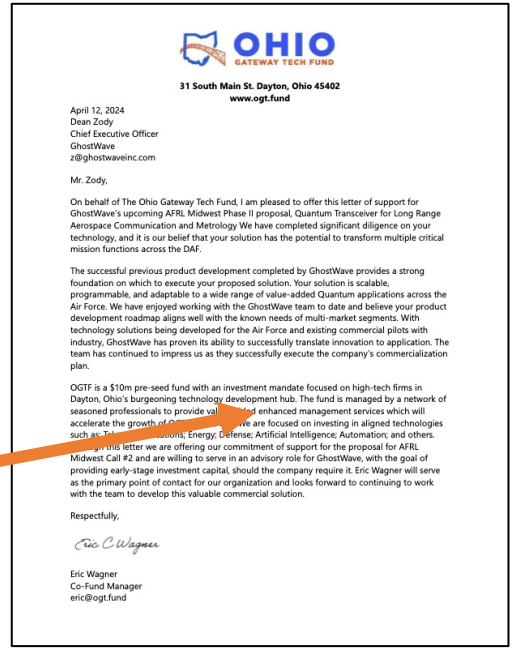
The AFRL Midwest program enables a technical dialogue and constructive feedback to further increase the TRL of the quantum Rydberg atom with **complex RF waveforms**. Significance of this to DoD, AFRL and AF include secure communications and improved accuracy in threat detection. Commercial Markets include information security in the business sector and health care applications.



Year vs Sales X-axis time, Y axis sales

Commercialization Plans/Follow On

- Commercialization specifics will be clarified as we test use cases of the Hybrid Model
- Volume Production can be at RF Board Assembly in Midwest (NuWaves RF Solutions), final test and ship at GhostWave
- Follow-on investment potential with Ohio Gateway Tech Fund
- Tech Licensing will be evaluated



OHIO GATEWAY TECH FUND

31 South Main St. Dayton, Ohio 45402
www.ogt.fund

April 12, 2024
Dean Zody
Chief Executive Officer
GhostWave
z@ghostwaveinc.com

Mr. Zody,

On behalf of The Ohio Gateway Tech Fund, I am pleased to offer this letter of support for GhostWave's upcoming AFRL Midwest Phase II proposal, Quantum Transceiver for Long Range Aerospace Communication and Metrology We have completed significant diligence on your technology, and it is our belief that your solution has the potential to transform multiple critical mission functions across the DAF.

The successful previous product development completed by GhostWave provides a strong foundation on which to execute your proposed solution. Your solution is scalable, programmable, and adaptable to a wide range of value-added Quantum applications across the Air Force. We have enjoyed working with the GhostWave team to date and believe your product development roadmap aligns well with the known needs of multi-market segments. With technology solutions being developed for the Air Force and existing commercial pilots with industry, GhostWave has proven its ability to successfully translate innovation to application. The team has continued to impress us as they successfully execute the company's commercialization plan.

OGTF is a $10m pre-seed fund with an investment mandate focused on high-tech firms in Dayton, Ohio's burgeoning technology development hub. The fund is managed by a network of seasoned professionals to provide val[illegible]ed enhanced management services which will accelerate the growth of [illegible]ve are focused on investing in aligned technologies such as: Te[illegible]ations; Energy; Defense; Artificial Intelligence; Automation; and others. [illegible] this letter we are offering our commitment of support for the proposal for AFRL Midwest Call #2 and are willing to serve in an advisory role for GhostWave, with the goal of providing early-stage investment capital, should the company require it. Eric Wagner will serve as the primary point of contact for our organization and looks forward to continuing to work with the team to develop this valuable commercial solution.

Respectfully,

Eric C Wagner

Eric Wagner
Co-Fund Manager
eric@ogt.fund

Transition significance

With all RF components that can "transmit", there will be regulatory approval. However, taking this hybrid approach of quantum and non-quantum co-existing on the same device, approvals are expected to be faster than a full quantum communication or radar device. **One of the key points is this hybrid approach will aid in faster acceptance and approval of Quantum RF**.

There will also be opportunities for small business growth and **technology licensing** or transition. Letter of support from OGTF

Key Objectives

SIGNED CONTRACT

T=0

T=6 MONTHS

1) Create Novel RF waveforms with) development kits (GhostWave)
2) Generate Non-metallic Rydberg atom arrays, (Infleqtion)
3) Demonstrate Wavelength converter, (GhostWave and Converge)
4) Initiate Design of Quantum algorithms (UDRI)

T=12 MONTHS

1) Collect Data for Characterize and Optimize sensitivity and bandwidth (AFRL)
2) Compile OFRN/AFRL Regional Network input to present program to others (All)
3) Demo Data for Spectrum Analysis of Quantum RF Signal (All)

T=18 MONTHS

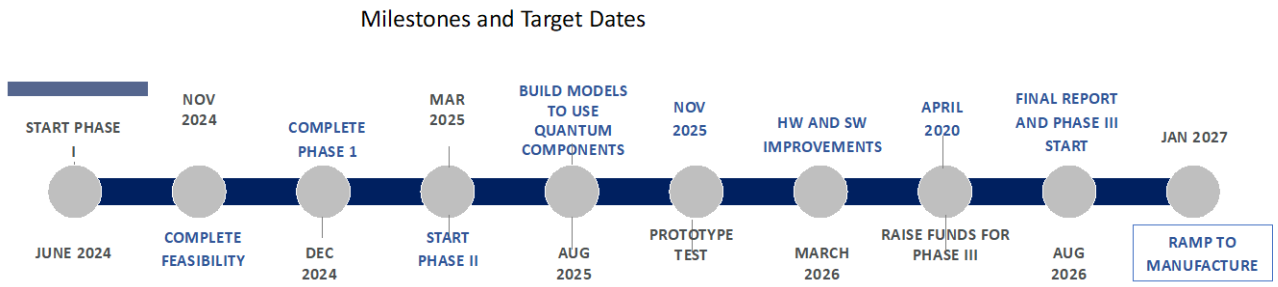
1) Collaboration with NASA and DOD
2) Building of Hybrid models to test/demo
3) Bring Quantum jobs to Midwest Region

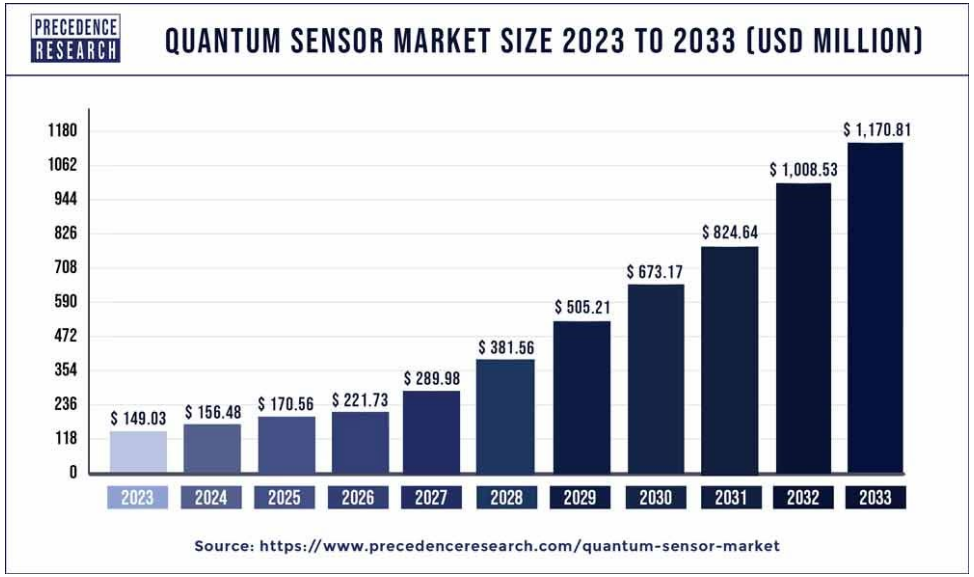
T=24 MONTHS

1) Use Case Reporting
2) Funding Identified for Phase III
3) Gain Advantage of Quantum careers in Midwest

Why Quantum - Market

- Analysis of market size and 1 and 5 year forecasted market share.
  - Global Quantum Sensor Market size to grow from $170M in 2025 to $505M in 2029
  - In year 1, we will have 0% market share
  - In year 5, market share of 10%





Year vs Sales X-axis time, Y axis sales

Explanation of milestones and target dates of plan to obtain that market share. Integration of the RF components will require extensive regulatory approval and testing. Gain Market Share through Marketing and DoD Prime direct sales.

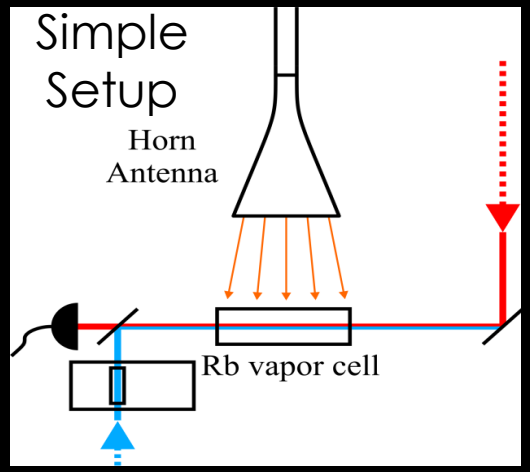
What experience do you have with marketing to this target market? Will hire an experienced Marketing Lead in Phase II

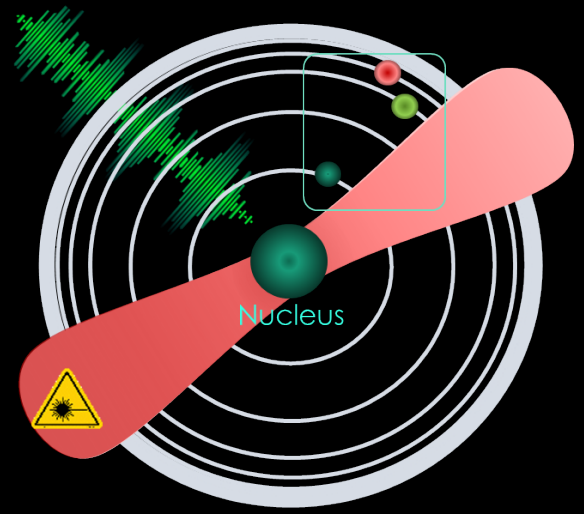
What commercialization strategy appears to be the best for bringing this product to the target market? Integrate Quantum RF components into existing/modified sensors. Be the supplier to DoD Primes for the quantum assemblies (sensors/communicatons) that integrate into their final equipment.

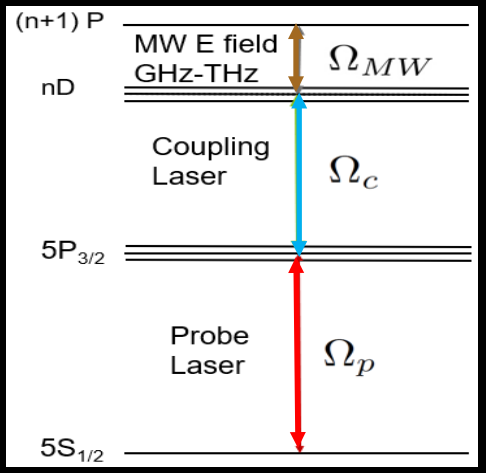
What experience do you have with bringing products to market – either through this company or through other companies with with which you have worked. John Bair on our team has experience with technical/electronic startup to taking company public and selling to Avnet

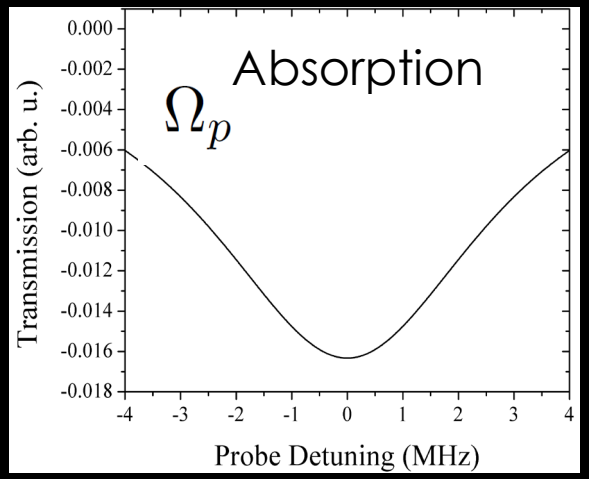
Does the company currently market, manufacture or license technology? Describe what you do. GhostWave is combining Quantum and non-Quantum equipment. We manufacture custom radar and radio technologies.

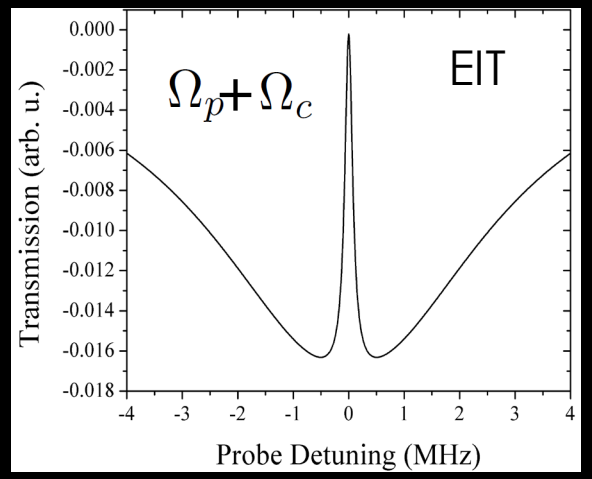
Quantum Sensing – How does it work?

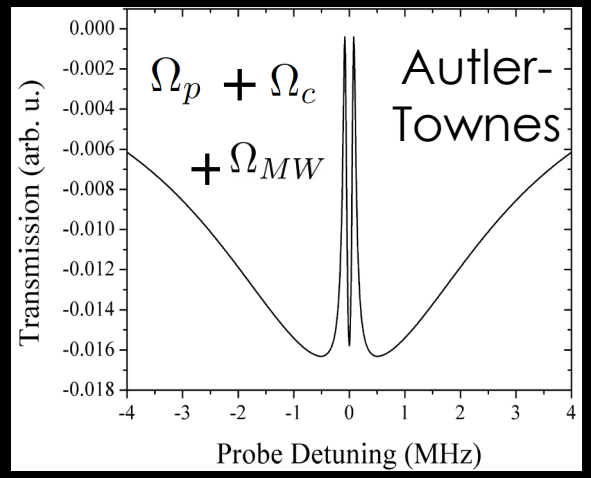












Fan et al, Atomic based RF sensing, J. Phy. B 48, 202001 (2015)

Quantum Sensing - Technical Merit

Quantum RF Sensors offer several benefits in a Hybrid application:

- High Sensitivity
- Wide Bandwidth
- Fast Response Time
- Compact Size
- Security
- Low Noise
- Quantum Advantage *

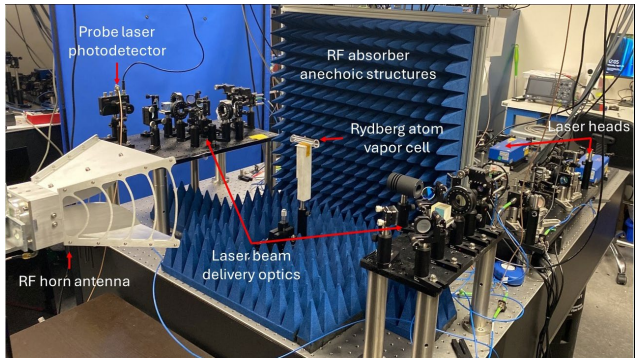
*Outperform Classical Sensors

Problem: Imprecision, Non-secure Communications, Spoofing, Intercepted data

Importance: Critical to safety and security of warfighters. Improved timing & accuracy. Configurable sensor networks.

Objective Increase dialogue with NASA and AFRL to build upon OFRN project with new use cases. Increase feasibility and to collaborate to raise TRL level

Expected Outcomes (explained) /Likelihood of meeting Objectives



1.Yes, with this increased AFRL Midwest support, the Team will meet their objectives of benchtop demonstrating new use cases.

2. Outcome: Results documented & reported to AFRL Midwest Region. Develop industry plan for growth. **Start discussions with other DoD.**

Risks and Mitigation Strategies

1. **Performance.** The Hybrid version of Quantum/Non-Quantum RF does not perform as expected due to Technical, Quantum Effects or Regulatory Issues. This is mitigated by upfront research to understand the environment and expected performance of the demonstration.

2. **Ensure performance metrics** (sensitivity, Instantaneous bandwidth, Noise Figure, etc.) of Rydberg Sensor have comparative equivalent to classical antenna/RF manifold. Initial metrics developed during the ORFN project and will be documented with the scheduled bench tests.

3. **Talent availability** of experts who understand Rydberg Atom Sensors. The mitigation strategy under the current Ohio Federal Research Network (OFRN) Quantum project is to leverage Ohio State advisors connecting the team to qualified talent (OSU PhD candidate is currently a GhostWave intern).

4. **Schedule Risk integration of Rydberg atom sensor** prototype under the OFRN project. Mitigation plan to adjust schedule ensuring prototype product is assessed to have more integrated features (i.e., wavelength converter PIC, Quantum algorithms hosted on SDR, etc.) The below System Hardware and Software Requirements and Acceptance table (Figure 1) will be used as a self-grading mechanism for the 24-month AFRL Midwest Region project and as a technology baseline for proposed RY Exploratory research projects.

Optical Frequency Converter – OSU

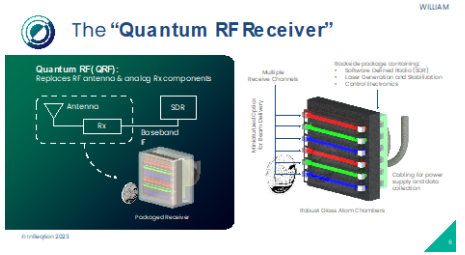
Item #	Requirement/Specification Description	Acceptance Method
4.1	Computational modeling of wavelength converter	Modal analysis, quasi-phase matching bandwidth and center frequency, relationship between second harmonic and fundamental.
4.2	Fabrication of wavelength converter	Inspection and analysis of optical micrographs and scanning electron micrographs of fabricated wavelength converter

Fig 1

Quantum Sensing - Collaboration

Opportunities to embed (move) personnel- AFRL Embed 2 PhDs to support OFRN RF Quantum Project

Embedded personnel to receive training and/or mentorship - Infleqtion provided weekly training at start of OFRN contract. This can be continued with AFRL Midwest Region agreement.

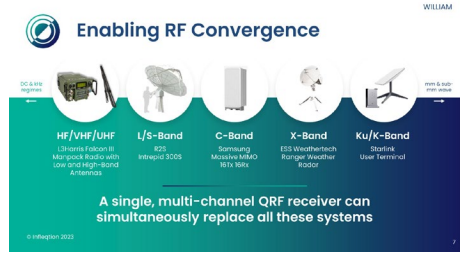


AFRL S&E personnel to be integrated into research Dr. Charles Cerny, Dr. Saba Mudaliar are fully engaged with this team. Weekly calls, Proposals, etc. Opportunities to collaborate with other organizations and/or partners – **NASA, Universities, USSF, Army DEVCOM, NRL**

Skill and knowledge transfer opportunities identified

Current project is collaboration between AFRL, Converge Technologies, UDRI, Ohio State U, and Infleqtion and GhostWave

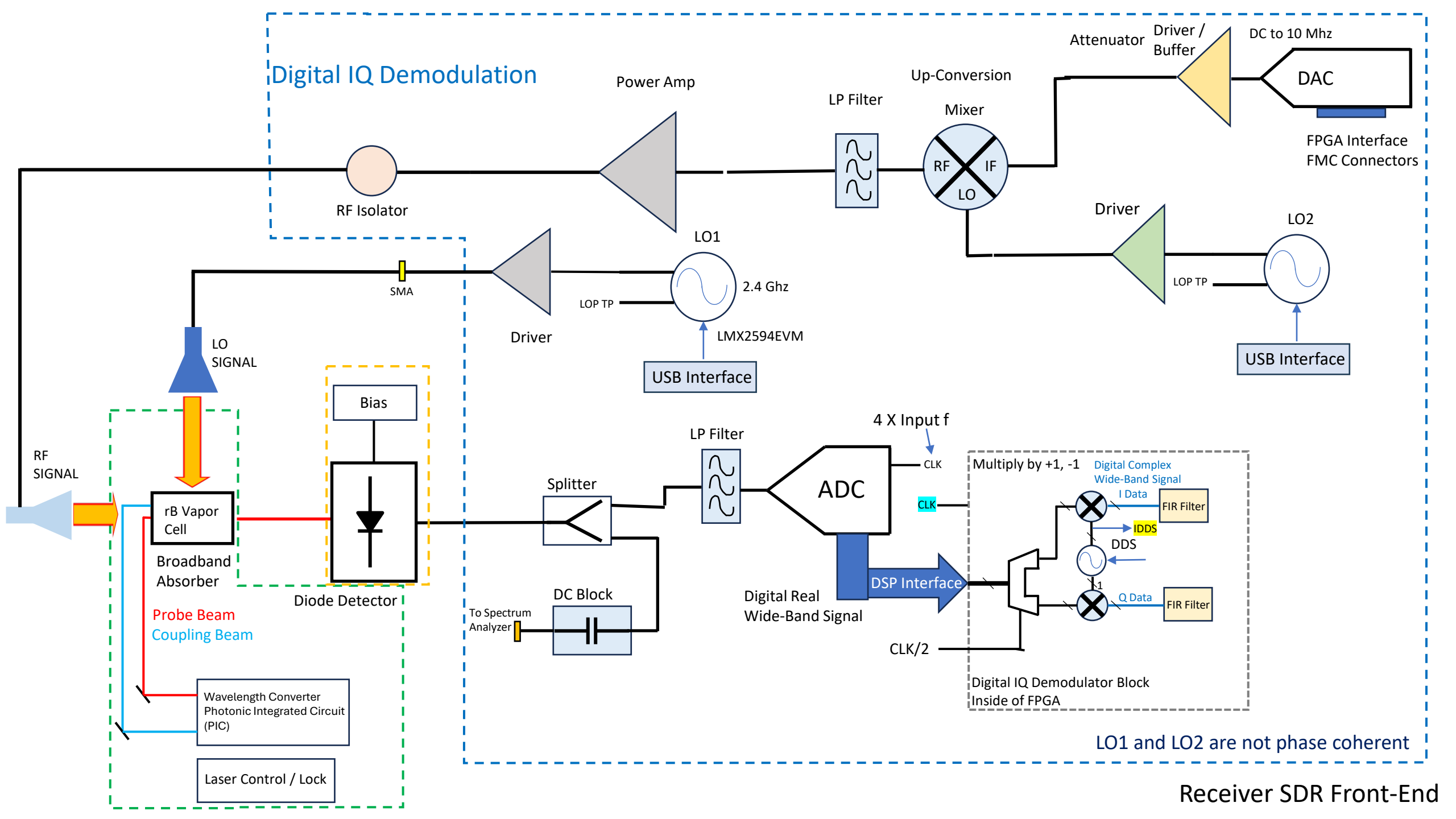
"By gaining hands-on access to commercial technologies, we believe we are enabling greater progress toward quantum technology breakthroughs," said Dr. Kathy-Anne Soderberg, AFRL senior scientist for quantum science and technology.



a) Two PhD student interns from Ohio State Univ. engage in different roles this semester.

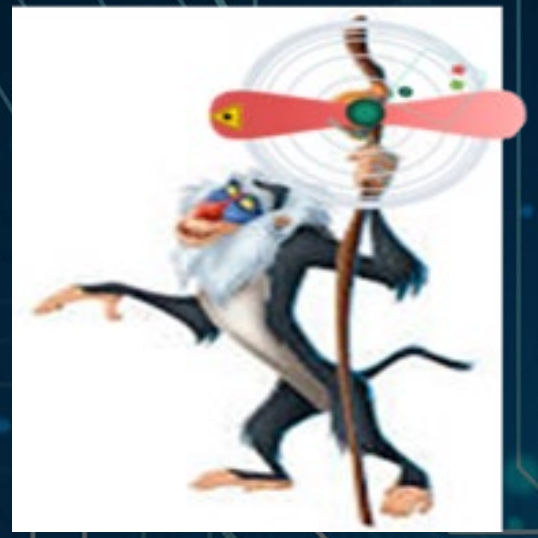
Skills and Knowledge Transfer (continued) and

The AFRL Sensors Directorate is currently participating as an "In-Kind Partner" under the OFRN Round 6 "Quantum Sensing Technologies" project, with the GhostWave team offering **technical knowledge insights** over the 18-month period of performance. **AFRL/RYM's strategy is to guide the GhostWave team to a successful Quantum Sensor demonstration** and provide a pathway for the documented results to be shared the larger Defense and Government communities who are part of a national initiative to develop Quantum Science. This is likely to lead to follow-on discussions regarding applications for Quantum Sensors and technology licensing and/or transition opportunities. **(From AFRL letter of support to OFRN)**


Digital IQ Demodulation
Power Amp
LP Filter
Up-Conversion
Mixer
Attenuator
Driver / Buffer
DC to 10 Mhz
DAC
FPGA Interface
FMC Connectors
RF
IF
LO
RF Isolator
Driver
LO2
LOP TP
USB Interface
LO1
2.4 Ghz
LOP TP
LMX2594EVM
USB Interface
SMA
Driver
LO SIGNAL
Bias
RF SIGNAL
rB Vapor Cell
Broadband Absorber
Diode Detector
Probe Beam
Coupling Beam
Splitter
LP Filter
4 X Input f
ADC
CLK
CLK
DC Block
To Spectrum Analyzer
Digital Real Wide-Band Signal
DSP Interface
CLK/2
Multiply by +1, -1
Digital Complex Wide-Band Signal
I Data
FIR Filter
IDDS
DDS
-1
Q Data
FIR Filter
Digital IQ Demodulator Block Inside of FPGA
Wavelength Converter Photonic Integrated Circuit (PIC)
Laser Control / Lock
LO1 and LO2 are not phase coherent
Receiver SDR Front-End

Future Directions (2024/25)

- OFRN Prototype Independent Testing in RY Range (Frequency Selectivity, Sensitivity & Interference Immunity) (Improved Methodology & Infrastructure for OneRY Range)
- OFRN Interns (MS & PhD Students) Workforce Eligible (Small Bus/AFRL)
- Rydberg Atom Direction Finding/Angle-of-Arrival Array techniques
- Development of highly integrated hardware with frequency selective SDR development
- Quantum RF algorithm refinement for complex waveform analysis & assessment
- Horizon scan of Quantum Sensing technology sector for customer opportunities (DoD, Gov't, etc.)
- Explore potential VC Partners (e.g., Ohio Gateway, Drive Capital. & Rev 1 Ventures) for Phase III



Questions ?

Parallax
ADVANCED RESEARCH

Ohio Federal Research Network
Driving Innovation Through Strategic Partnerships

Opportunity Review

Health Science Futures: Office-Wide Innovative Solutions Opening for Advanced Research Projects Agency for Health

Solicitation # ARPA-H-SOL-24-104

- **Who**
  - *Gov't*: Department of Health and Human Services
  - *Eligibility*: ALL
- **What**
  - The type of solicitation: Grant
- **When**
  - Released: Mar 14, 2024
  - Due: Mar 14, 2025
- **Where**
  - Webpage: grants.gov
  - Contact information: Mark E Baxter
    - Contract Specialist
    - Phone 3018274852
    - mark.baxter@arpa-h.gov
- **Why**
  - *Funding*
    - *N/A*
    - Expecting 100 Awards
  - *Technical*
    - **ISO seeks** solution summaries & proposals for projects within the general scope of the ARPA-H Health Science Futures mission office.
    - **Platform Systems**: Innovative approaches at the intersection of artificial intelligence, high performance computing (including quantum computing) and biological systems, including enabling de novo design of biomolecules with entirely new phenotypes.

Thermal Transport Processes

Solicitation # PD-23-1406

- **Who**
  - *Gov't*: National Science Foundation
  - *Eligibility*: Unrestricted
- **What**
  - The type of solicitation: Grant
- **When**
  - Released: Apr 05, 2023
  - Due: Proposals accepted anytime
- **Where**
  - Webpage: grants.gov
  - Contact information:
  - NSF grants.gov support
  - grantsgovsupport@nsf.gov
- **Why**
  - *Funding*
    - Estimated Total Program Funding of **$7,047,000**
  - *Technical*
    - **Thermal science and quantum technology interface**: Quantum sensors for thermal measurements; quantum computing for thermal sciences; thermodynamics and novel cryogenic cooling concepts for quantum devices; thermal transport in quantum materials and quantum phenomena; thermal solutions for next-generation qubits, qubit coupling, and quantum information storage.

LPS Qubit Collaboratory (LQC)

Solicitation # W911NF21S0009

- **Who**
  - *Gov't*: Dept of the Army -- Materiel Command
  - *Eligibility* : All U.S. entities
- **What**
  - The type of solicitation: BAA, grant
- **When**
  - Released: Apr 16, 2021
  - Due: May 30, 2026
- **Where**
  - Webpage: grants.gov
  - Contact information: Dr. T.R. Govindan
    - Technical Program Point of Contact (ARO)
    - t.r.govindan.civ@army.mil
    - usarmy.rtp.devcom-arl.mesg.qcbox@army.mil
- **Why**
  - *Funding*
    - *N/A*
  - *Technical*
    - Incubator, Collaboration, and Fellowship research proposals for LPS Qubit Collaboratory (LQC)
    - 1) pursue disruptive fundamental research and enabling technologies with a focus on qubit development for quantum computing and other applications (such as sensing);
    - 2) grow deep, collaborative partnerships to tackle the most difficult and relevant long-term problems in quantum information science and technology; and
    - 3) build a quantum workforce of tomorrow through research experiences in government at LPS and at LQC partners.

Global Information and Communications Technology (ICT) and Critical and Emerging Technology (CET) Standards

Solicitation # DFOP0016578

- **Who**
  - *Gov't*: Bureau of Cyberspace and Digital Policy
  - *Eligibility*:
    - Nonprofits having a 501(c)(3) status with the IRS
- **What**
  - The type of solicitation: Grant
- **When**
  - Released: May 21, 2024
  - Due: July 15, 2024
- **Where**
  - Webpage: grants.gov
  - Contact information:
    - Digital Connectivity & Cybersecurity Partnership DCCP-Info@state.gov
- **Why**
  - *Funding*
    - *Award information* –
    - $ 2,000,000 - $2,250,000
  - *Technical*
    - Supporting an international standards development process grounded in transparency, private sector leadership and public sector support, and diverse stakeholder engagement.

Helpful Links

1. SAM.gov – Contract opportunities
2. GRANTS.gov – Federal funding opportunities
3. SBIR.gov – SBIR/STTR information and solicitations
4. defensesbirsttr.mil – DoD-specific solicitation information
5. dodsbirsttr.mil – DoD-specific solicitations
6. sbir.nasa.gov – NASA-specific solicitations
7. ohiofrn.org – Help with identifying opportunities, matchmaking, and proposal development
8. apex-innovates.org – Help with SBIR/STTR process navigation and matchmaking

Upcoming Events

- **NSIN OnRamp Hubs OH, WA & AZ webinar - Congested and Contested Comms –** virtual, June 28
- **NAECON –** in-person, July 18
- **Farnborough International Airshow** – in-person @ Farnborough UK, July 22-26
- **FAA Symposium x AAM Summit** - in-person @ Baltimore, MD, July 30-August 1
- **LCID/WDI –** in-person @ Dayton Convention Center, Dayton OH, July 29-August 2
- **NDIA Emerging Technologies For Defense Conference & Exhibition –** in-person @Washington DC, August 7
- **146th NGAUS General Conference & Exhibition** – in person @ Detroit, MI, August 26
- **Launch Dayton Startup Week** – in-person, September 12
- **AFA National Convention** – in-person @ National Harbor, MD, September 14-15
- **Export Compliance Roadshow with Dept. Of Commerce** – in-person @ OAI, Cleveland, OH, September 17
- **AFA Air, Space & Cyber Conference** – in-person @ National Harbor, MD, September 16-18
- **DDC AAM Forum** – in-person @ Dayton OH, September 19
- **Hypersonic Technology & Systems Conference** - in-person @ North Logan, UT September 23-26
- **Global Aerospace Update and Outlook** – in-person @ OAI, Cleveland OH, September 25

Thank you

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