

# *Quantum Information Science at the University of New Mexico*



| QUANTUM NEW MEXICO >

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Director, Center for Quantum Information and Control







# What is Information?

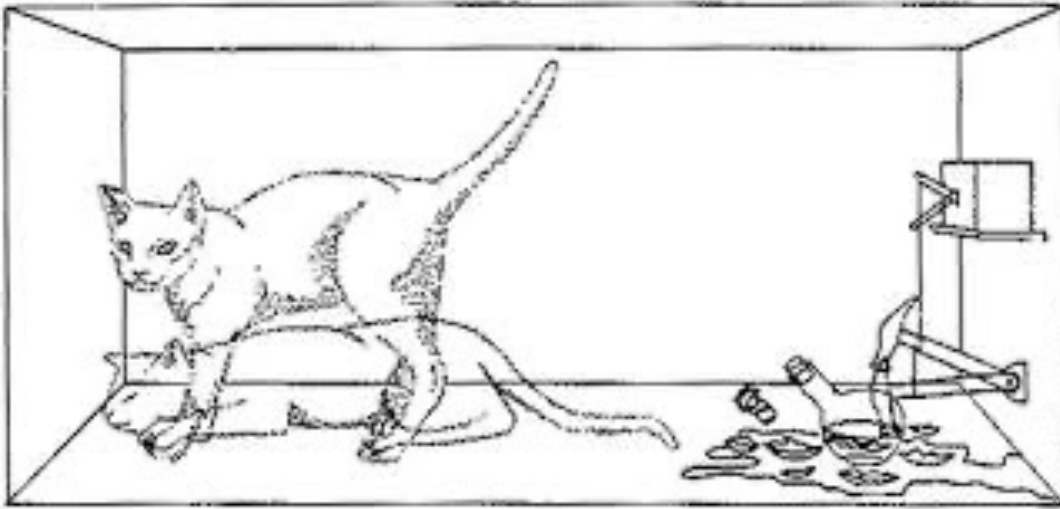
*What is the chance my guess is correct given the data I have?*

- Information is about *what we know*.
- We make predictions about the world around us based on prior information and *logic*.

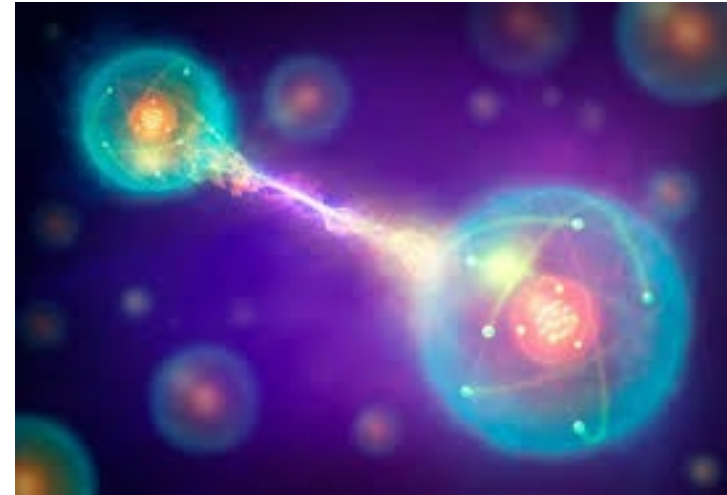
Probability my guess is true



# *Quantum Mechanics is Illogical*

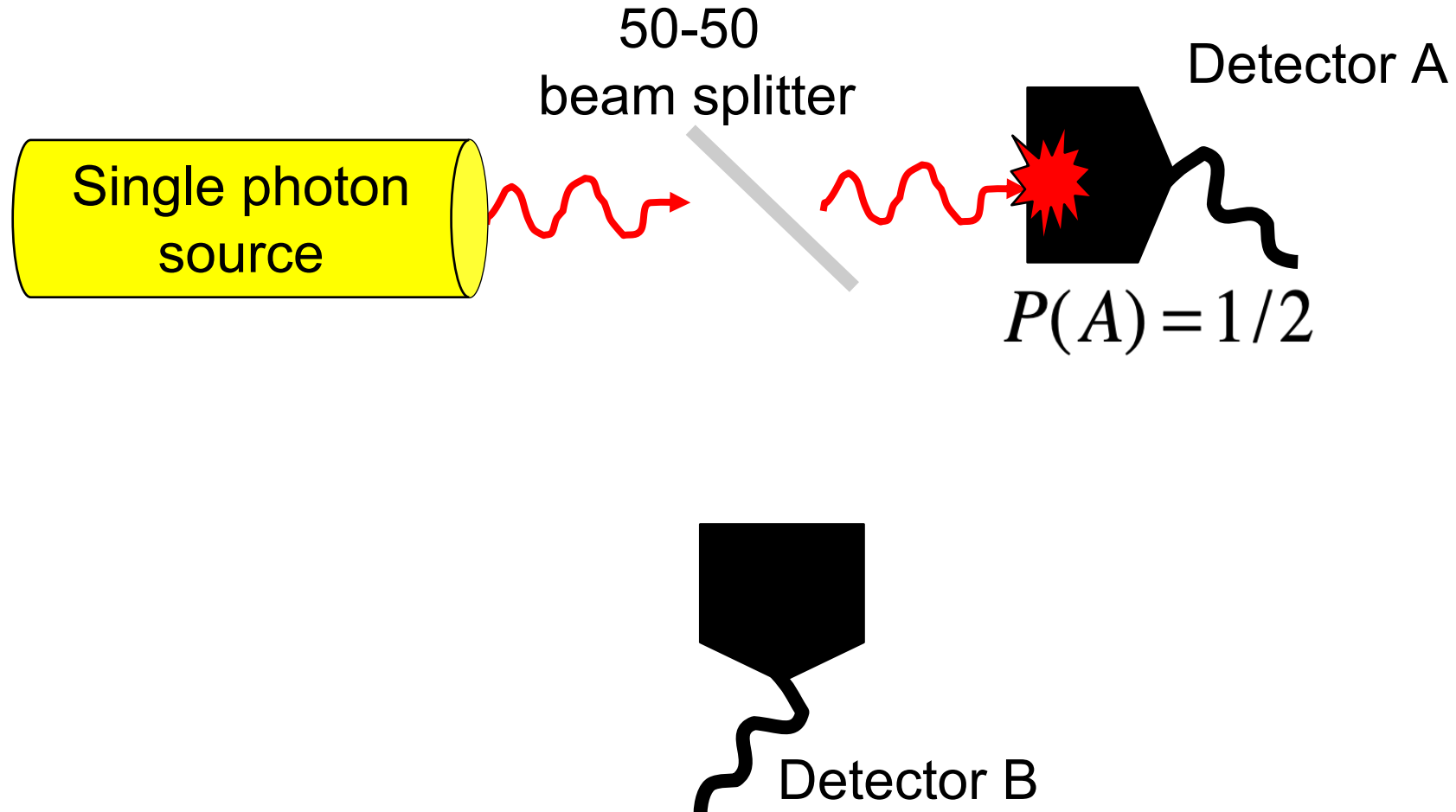


**Schrödinger's Cat**

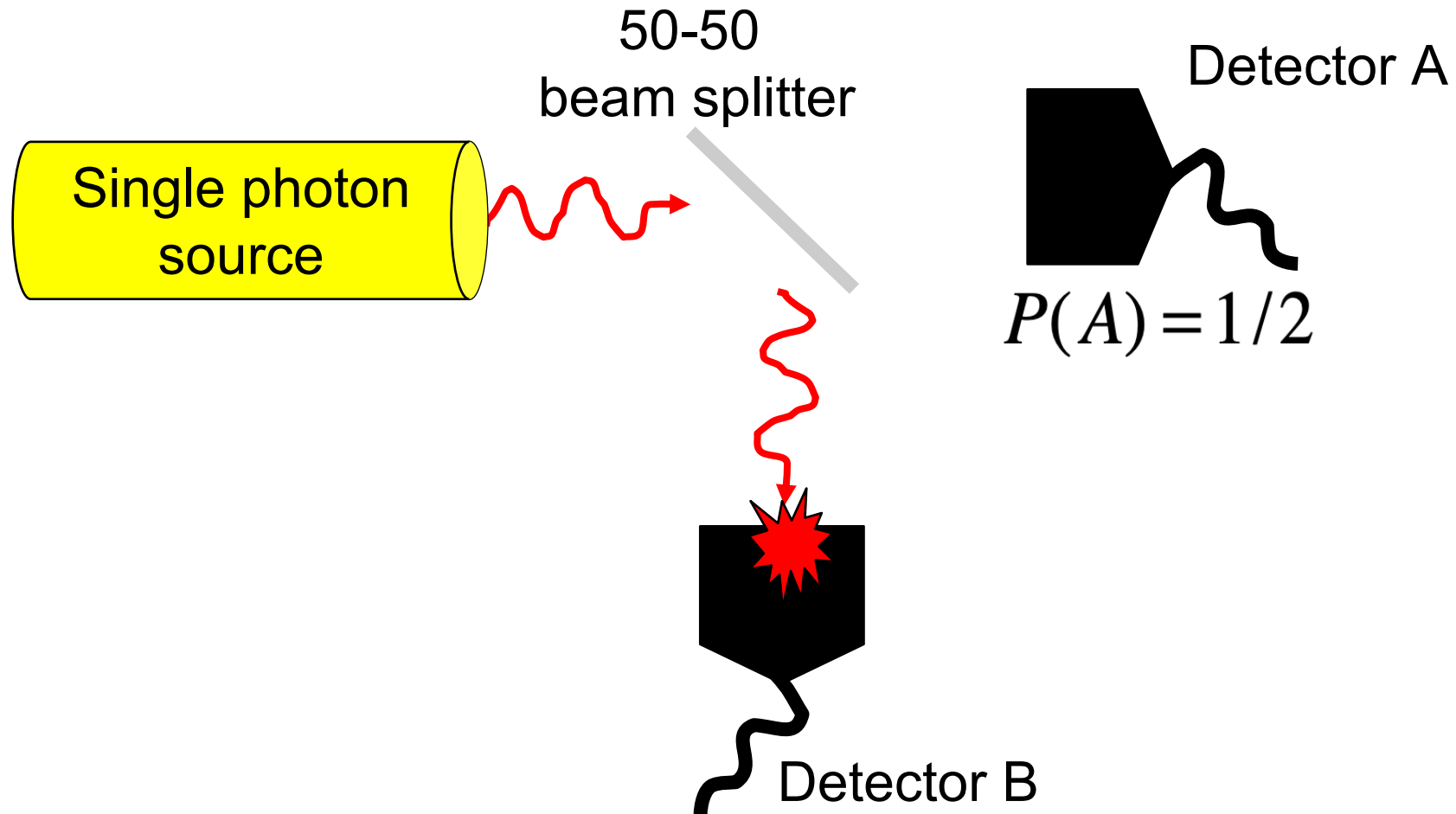


**Entanglement**

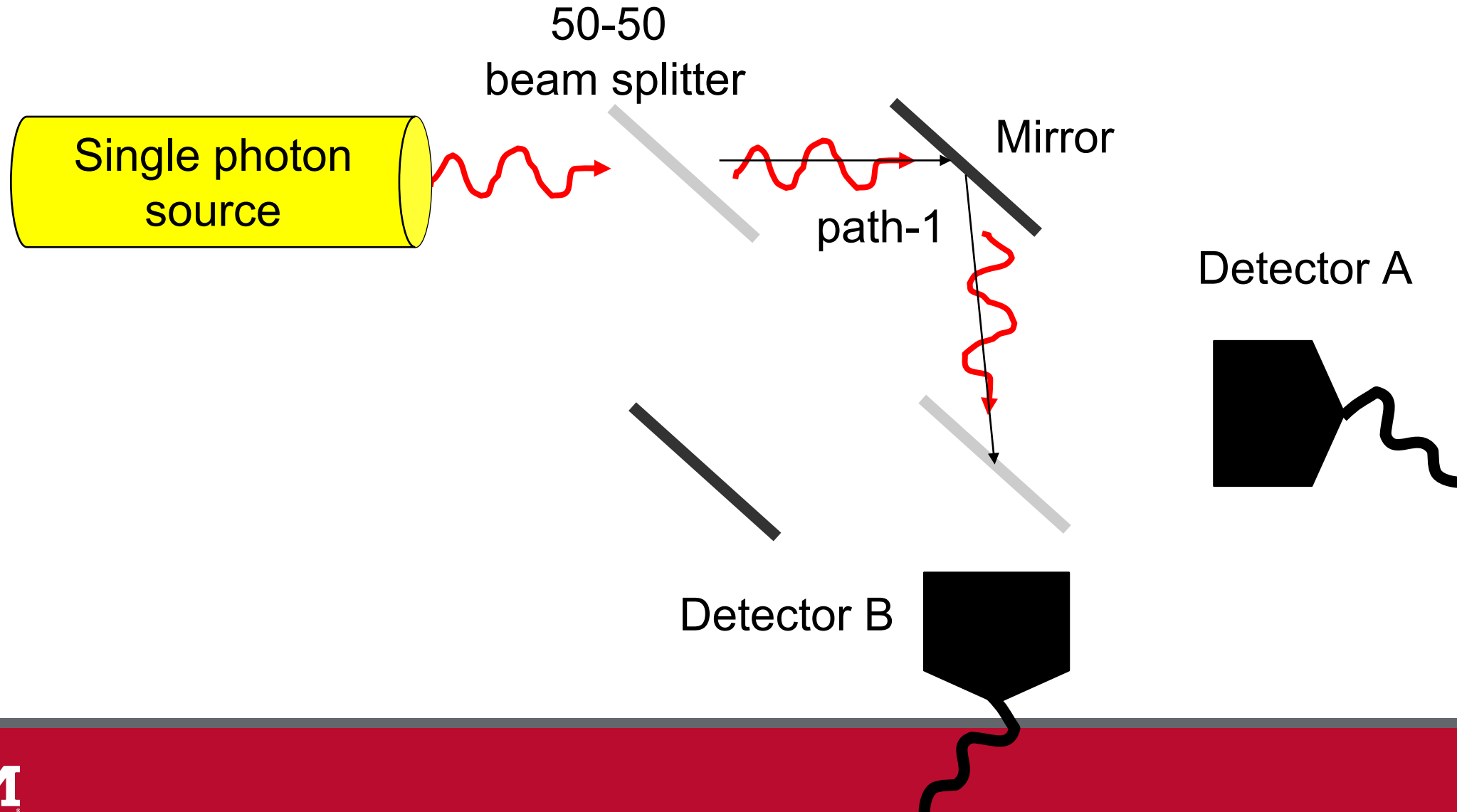
# Probabilities of Events, Quantum World



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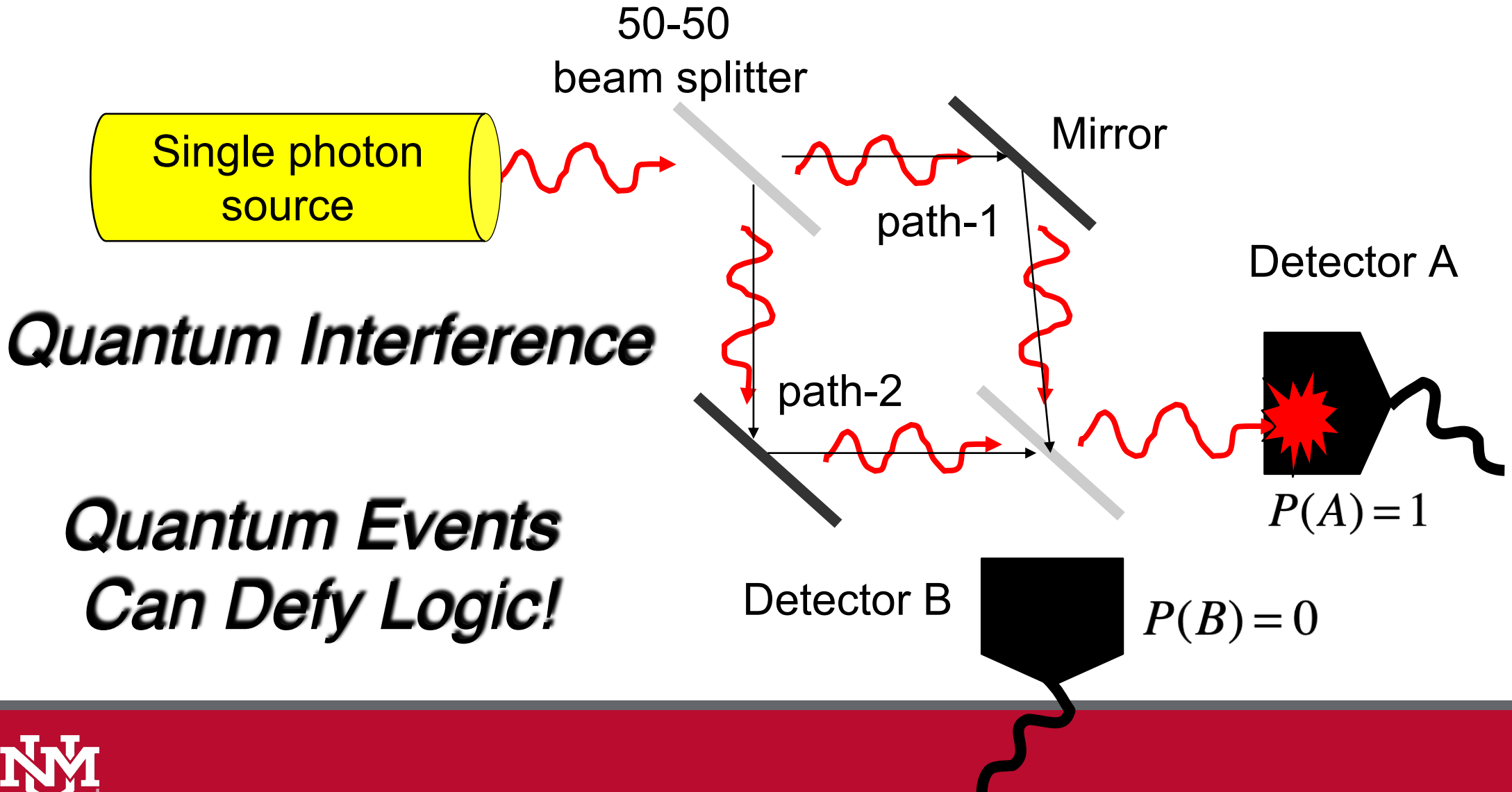


# Probabilities of Events, Quantum World

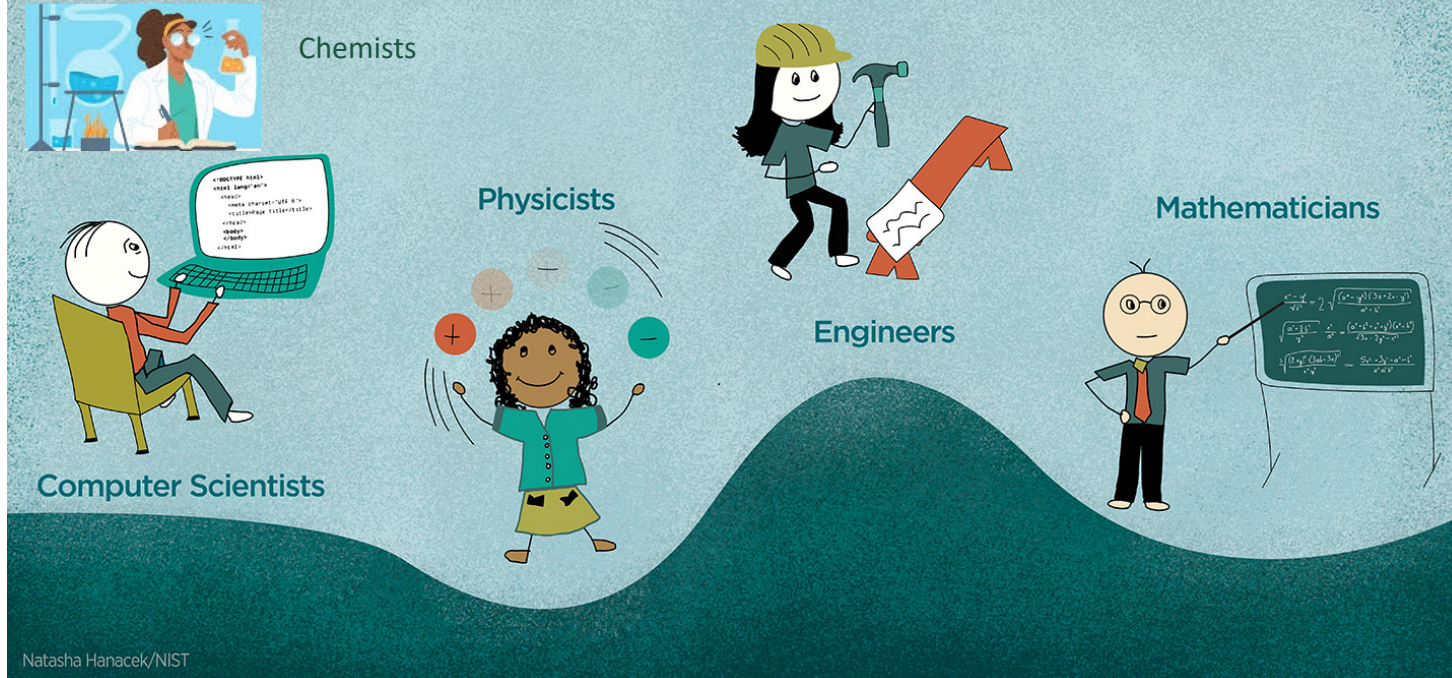




# Probabilities of Events, Quantum World



# QUANTUM INFORMATION



<https://www.nist.gov/topics/physics/introduction-new-quantum-revolution/second-quantum-revolution>

- **Quantum Information Science: An *interdisciplinary* field that marries two great pillars of the 20<sup>th</sup> century: Quantum Physics and Information Science.**

# *Information Processing*

**Communication:** Transmitting, sharing/hiding information

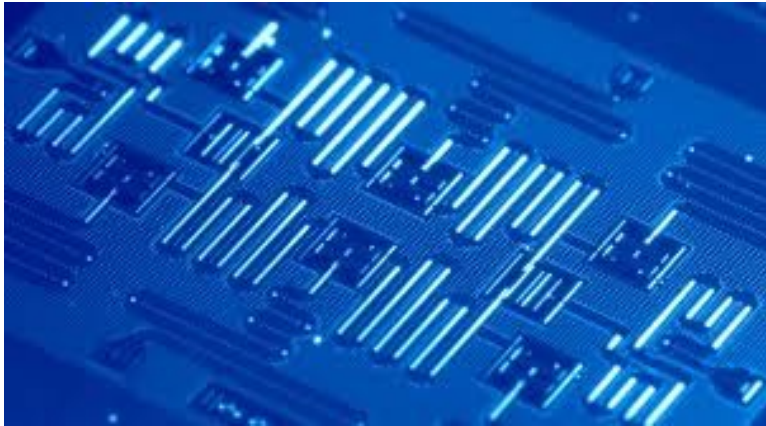


**Computation:** Executing an algorithm: Doing a mathematical calculation, Google search, predicting the weather....

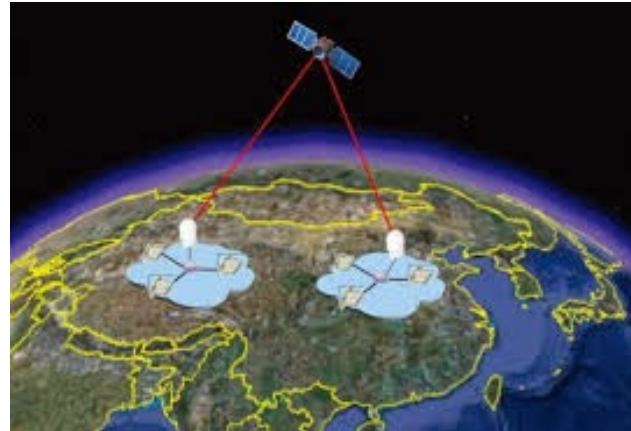




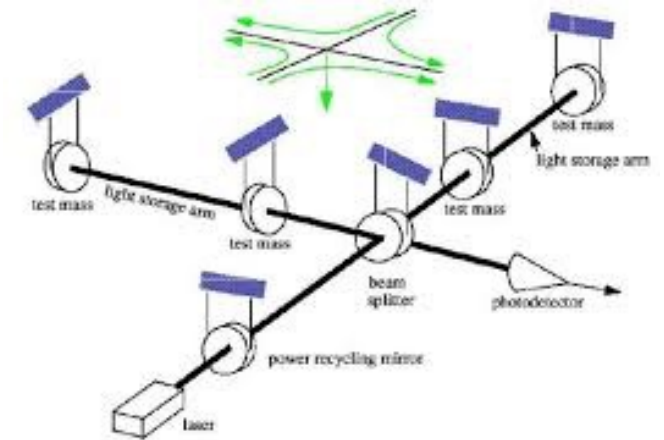
# The Pillars of Quantum Information Science



Quantum Computing



Quantum Communication



Quantum Sensing

## Technology

Harnessing quantum coherence and correlations for information processing



## Fundamental Science

Quantum Information informs foundations

- Complexity – matter and fields
- Quantum gravity and black holes
- Chemical processes

# *The Impact of Quantum Information Science*

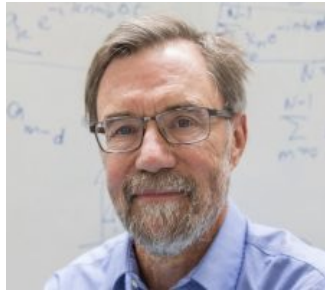
- **Quantum Computation:** Potential to radically speed up algorithms for applications such as chemical development, drug discovery, traffic optimization, climate forecasting.
- **Quantum Communication:** Cyber security: Breaking secret codes and creating unbreakable codes set by the laws of physics. Quantum addressed the energy costs of communication and computation.
- **Quantum Sensing:** Detecting the tiniest signals such as in biology, medicine, astronomy, and cosmology.

**New Mexico to train the develop the Quantum workforce of the future**

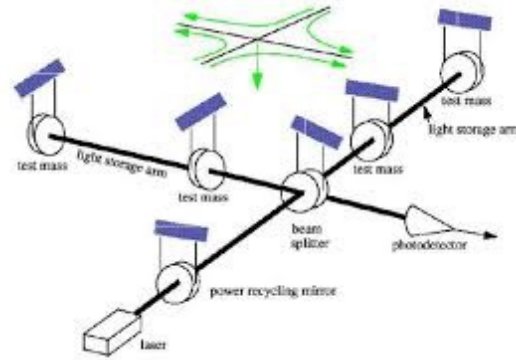


# UNM's Long History in QIS

- 1992: Carl Caves Establishes the Information Physics Group



National Academy of Sciences, 2020



- 2005: Center for Advanced Studies devoted to QIS.
- 2009: The Center for Quantum Information and Control (CQuIC) was created, funded by the National Science Foundation.
- 2016: CQuIC became an NSF-funded Focused Research Hub in Theoretical Physics (FRHTP) – one of two in the nation.
  - 6 core faculty, 18 associate faculty, 4 postdocs, 25 students

# UNM's Rich QIS Ecosystem

## UNM Departments



## Centers and Institutes



CQuIC

Center for Quantum Information & Control



Center for High Technology Material

**CARC**

Center for Advanced Research Computing

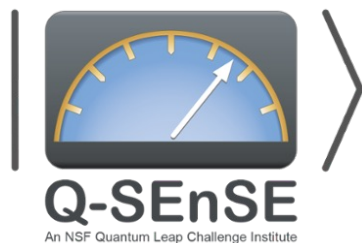
## National Laboratories



## National QIS Centers



*NSF FRHTP  
National QIS Theory Hub*



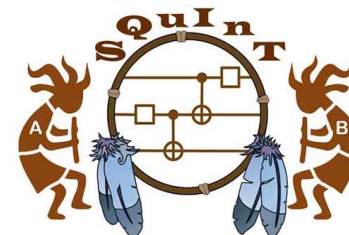
*NSF QLCI  
National QIS Theory Hub*



**QUANTUM SYSTEMS ACCELERATOR**  
Catalyzing the Quantum Ecosystem

*DOE  
QIS Centers*

## Outreach



Southwest Quantum  
Information and  
Technology

**QU-REACH**

Quantum  
Undergraduate  
Research Experience  
at the CHTM

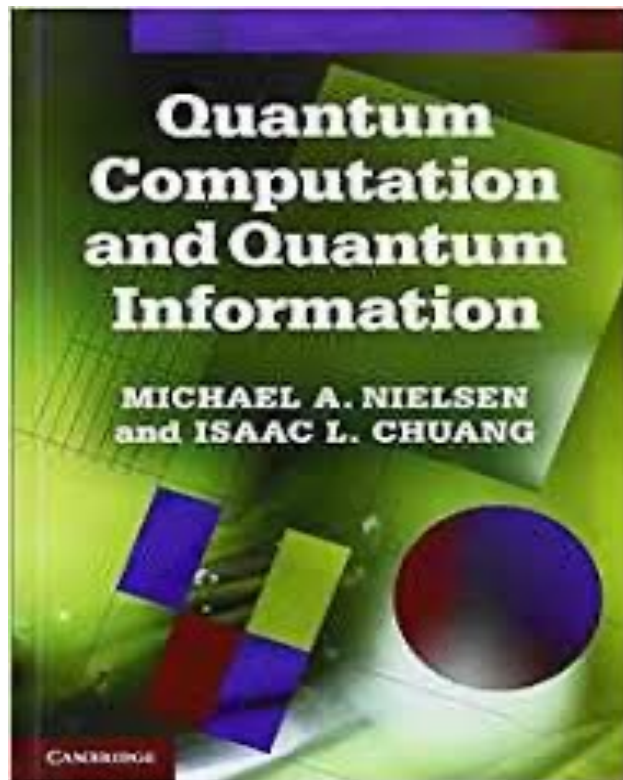


Quantum Computing  
Summer School



QCaMP  
Quantum Computing Math & Physics

# *New Mexico: A Deep History in QIS*



Michael Nielsen (UNM 1998):  
Y Combinator Research



Isaac Chuang (LANL 1998)  
MIT

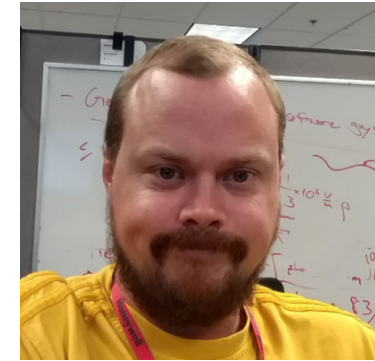
# UNM: Training a New Generation in QIS Leaders



Sergio Boixo: Google



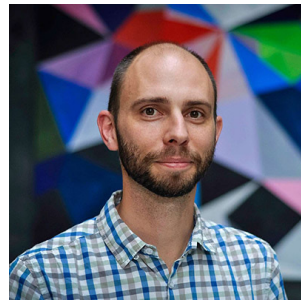
Shohini Ghose: TED Fellow,  
Director Women in Science, Wilfrid Laurier



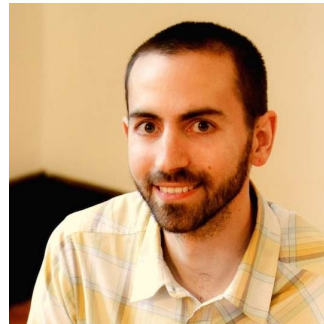
David Hayes  
Quantinuum



Raf Alexander  
Xanadu



Josh Combes  
CU Boulder



Steve Flammia  
Amazon



Sayonee Ray  
IonQ



Travis Scholten  
IBM



# UNM-Sandia-Los Alamos: Student Researchers



J. Anderson



C. Cesare



B. Chase



A. Chowdhury



A. Hankin



A. Orozco



H. Partner



A. Rakholia



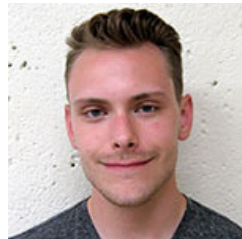
C. Ryan-Anderson



T. Scholten



B. Tabakov



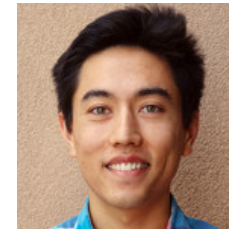
J. Bainbridge



M. Brickson



K. Campbell



M. Chow



B. Morrison

# Next Steps: The QNM Project



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“New Mexico is a Quantum State”

# *Quantum New Mexico (QNM)*



## QNM Institute (QNM-I)

### UNM-Sandia Joint Research Institute

**Workforce Development:** Retention of top talent, stronger recruiting opportunities, and reliable pipeline for new employees

**Basic Research:** Expanded access to basic research to enhance DOE-SC and NSF research programs leverage resources from both recently funded NSF and DOE centers and greater access to future funding opportunities.

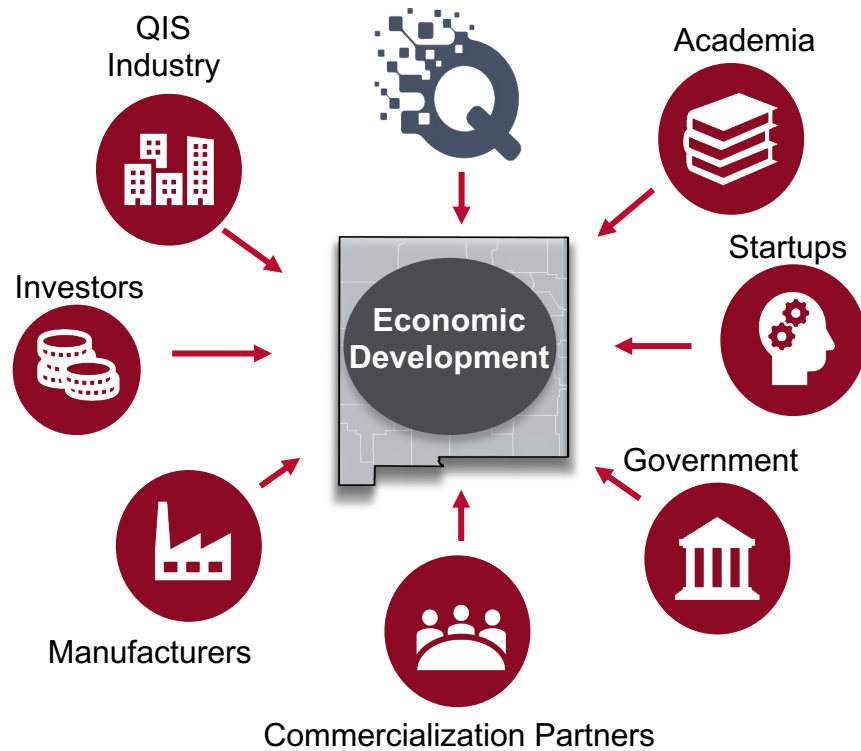
**QIS Industry and Partnerships:** Spearhead end-to-end transformation across New Mexico's QIS Startup Ecosystem through strategic technology transfer and business development support

# Quantum New Mexico (QNM)

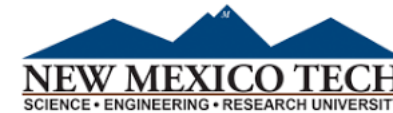


## QNM Collation (QNM-C)

### Creating and Quantum Technology Hub in New Mexico



### Broadening the Quantum Ecosystem



### Building the IT scaffolding for the Quantum Future

- Broadband
- Cloud computing
- Advanced manufacturing and materials