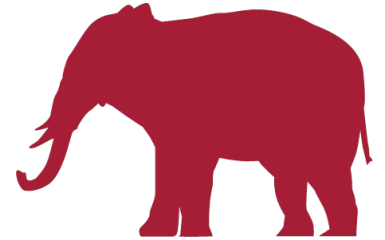


# Training the Next Generation PNT Engineers and Scientists

Thejesh N. Bandi, Ph.D.  
Associate Professor & Principal Investigator



**P**ositioning, **N**avigation, **T**iming, and **F**requency (**PNTF**) **Lab**  
<https://PNTFLab.ua.edu>

Department of Physics & Astronomy  
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THE UNIVERSITY OF  
**ALABAMA**

College of  
Arts & Sciences



# **OUTLINE** | Past, Present to Future!



- **Motivation**
- **PNT**
  - ✓ **Infrastructure strength**
  - ✓ **Needs: problems & solutions**
  - ✓ **UA contribution**
- **Outlook: Collaboration and benefits**

## PNT is a silent & ubiquitous infrastructure

### Need for PNT training & sustenance

- *Core problem: greying of the resourceful manpower*
- *Need of resources for future growth*

**Even if we only consider sectors with direct use of precise timing, we still must consider \$10.8 Trillion dollars each year to be vulnerable to active attacks or lack of manpower in the field.**

- ✓ *Financial Markets (\$5.9 Trillion, 18.2% of 2016 GDP).*
- ✓ *Transportation and Navigation (\$2.1 Trillion, 6.5%).*
- ✓ *Telecommunications (\$1.6 Trillion, 5.0%).*
- ✓ *Defense (Federal discretionary spending only! \$614 billion, 2.0%).*
- ✓ *Energy (\$580 Billion, 1.8%).*

# Motivation | Academic contributions to PNT

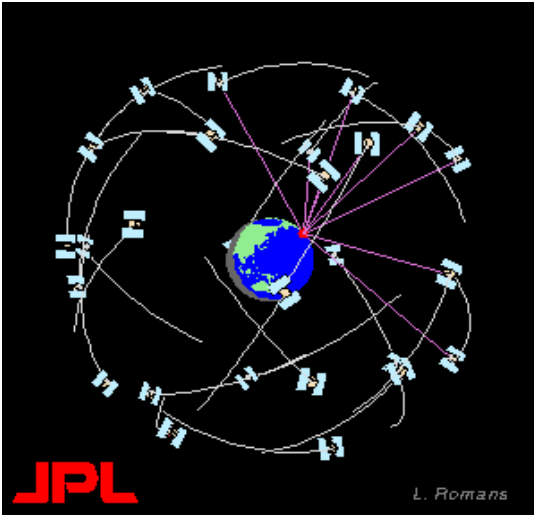
*General public response:  
“I have no idea what this is.”*

*General academic response:  
“That’s not novel, it’s been invented.”*

- ❖ *Interdisciplinary teaching, training and R&D.*
- ❖ *Manpower development identified with industry and government partners.*

- Existing clocks currently in use will continue to be used for the next 20+ years as they have the last 20+ years.
- Interdisciplinary students (physics, engineering, statistics, metrology) are needed to maintain the time & frequency infrastructure.
- Current PT equipment can benefit from leveraging specialists to innovate and improve current systems.
- R&D for future products

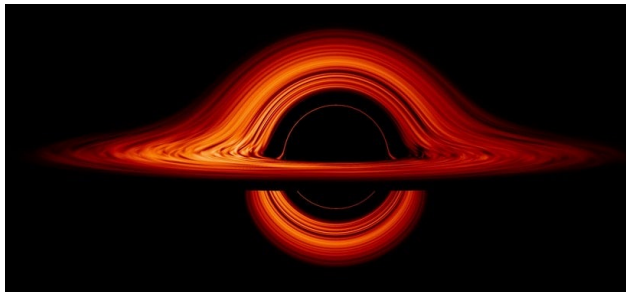
# PNT | Infrastructure and dependency



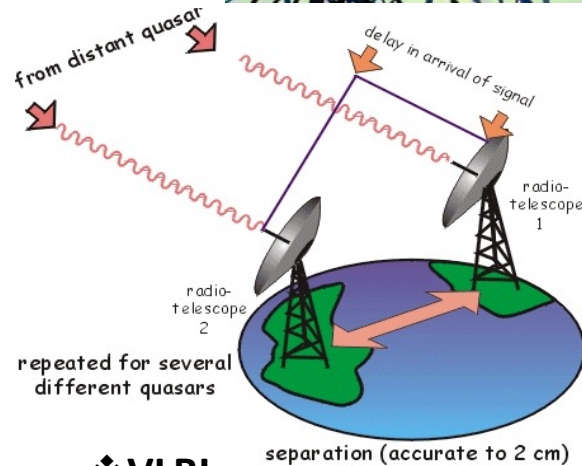
## ❖ Telecommunication synchronization



## ❖ GNSS: Global Navigation Satellite Systems (GPS, Galileo, GLONASS, Beidou, NavIC...)



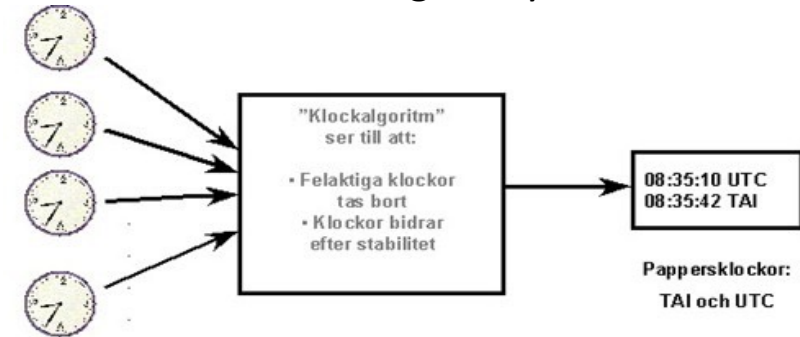
Black hole imaging



## ❖ VLBI



## ❖ Power grids synchronization



## ❖ Time keeping

Images credit: Internet

# PNT | Infrastructure and dependency

## ❖ Aviation

## ❖ Accurate predictions

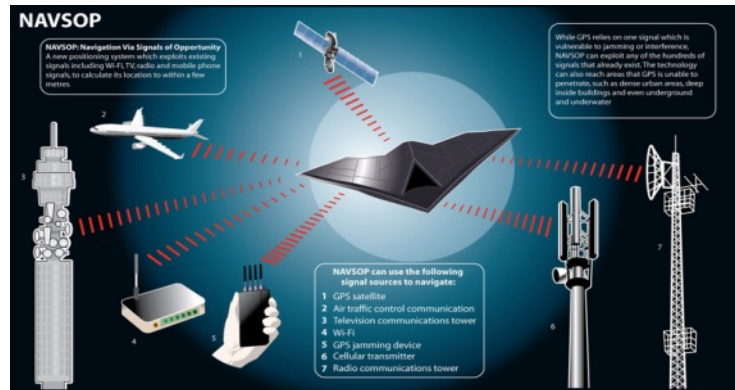
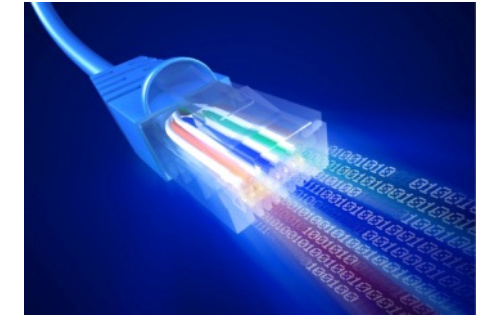
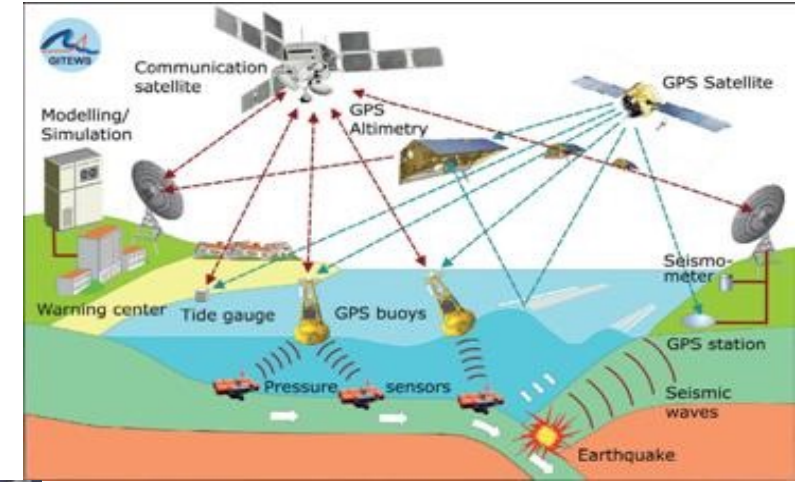
- Weather
- Earth quake real-time monitoring
- Cyclones
- Atmospheric humidity analysis

## ❖ Synchronization of high-speed internet

## ❖ Precise science experiments on ground and space

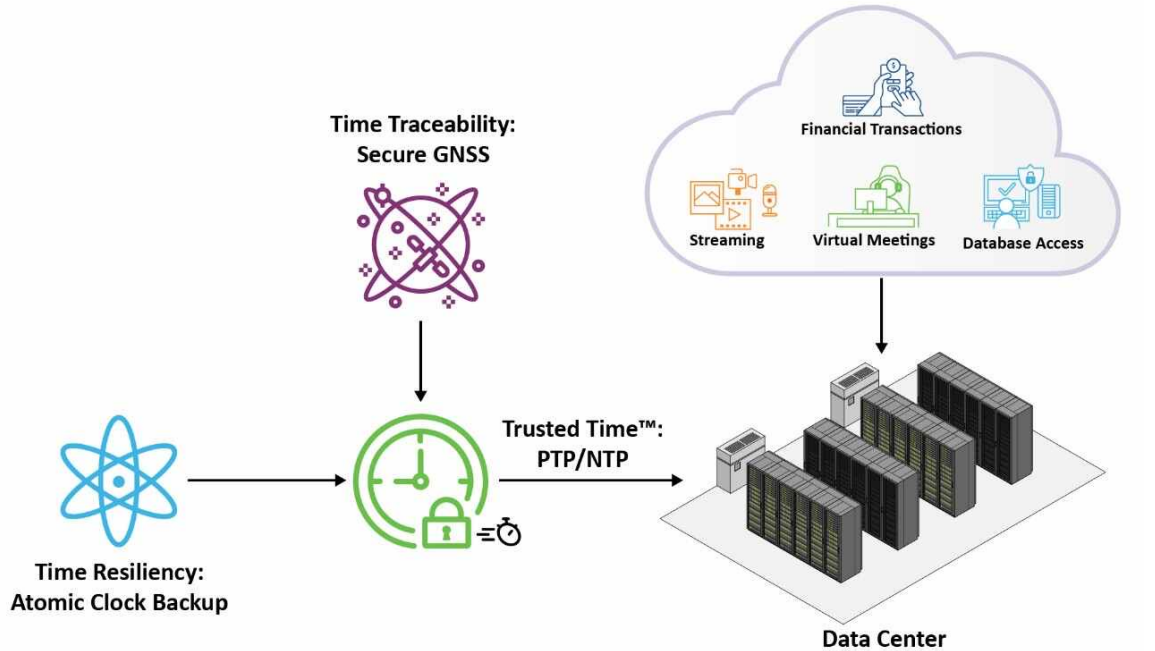
## ❖ Military uses

❖ And....  
**MANY MORE !!**



Images credit: Internet

# PNT | Infrastructure and dependency



Time synchronization for data center. Credit: Microchip

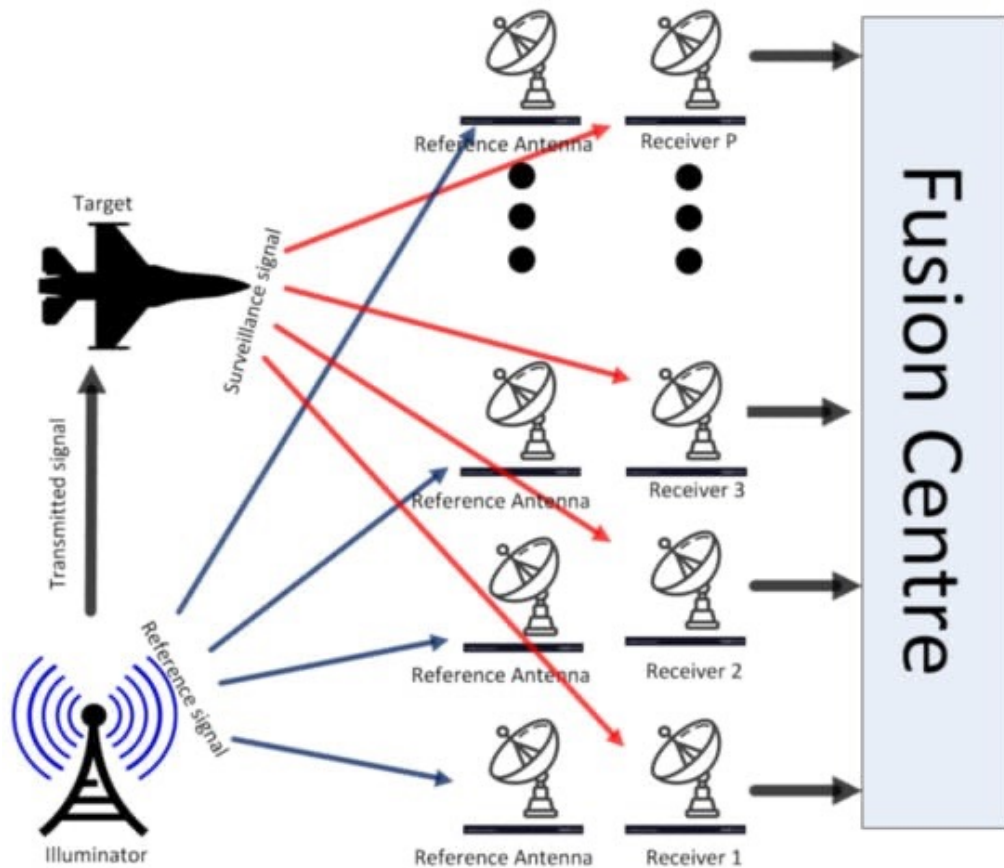


Central cooling plant in Google's data center.  
Credit: Google/Connie Zhou

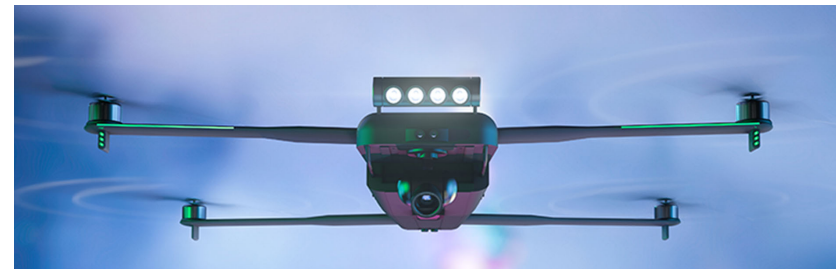
❖ Cloud computing, networking & Synchronization



# PNT | Infrastructure and dependency



Credit: IEEE Spectrum



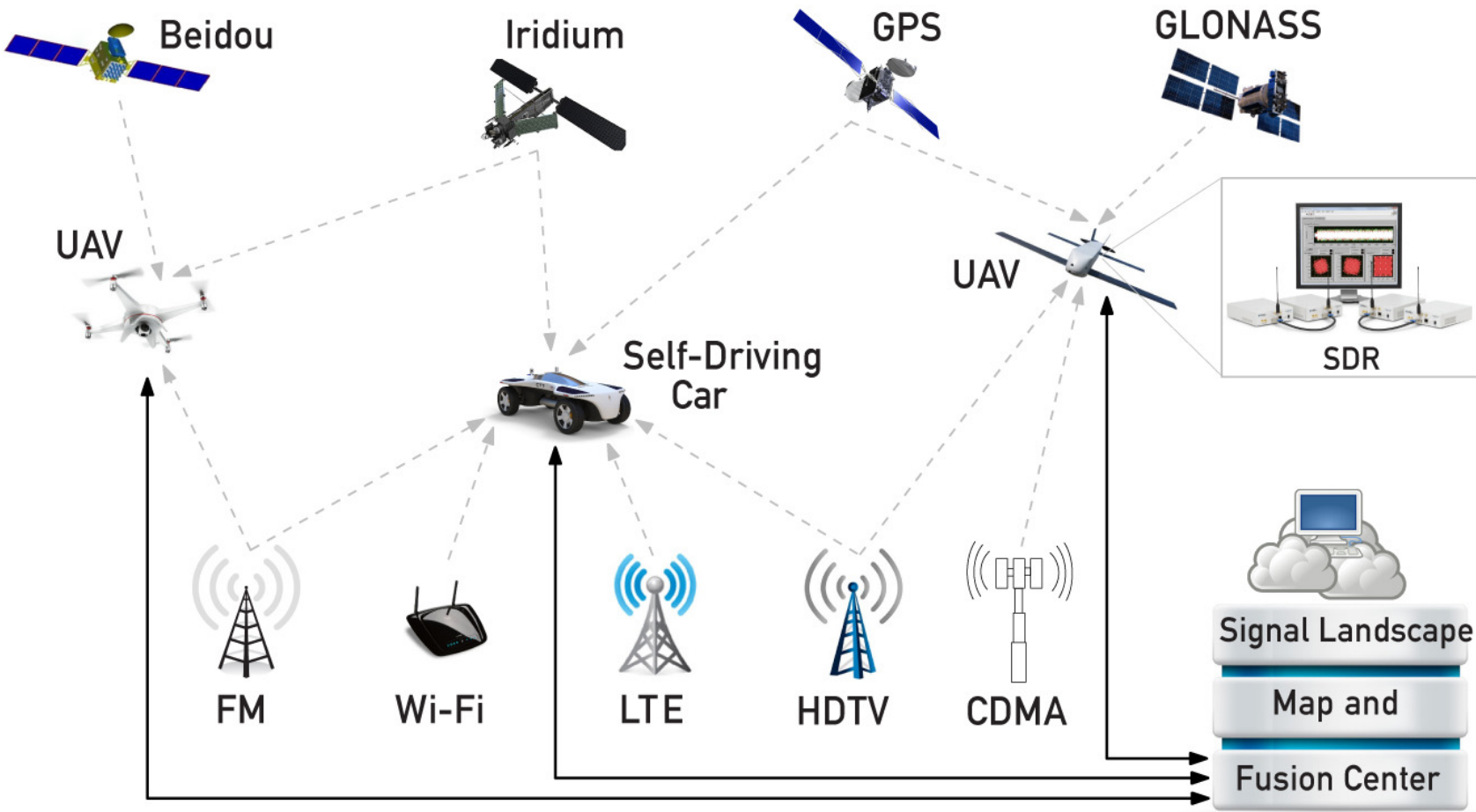
Credit: Getty Images/iStockphoto

Credit: A. Asif & S. Kandeepan, *Sensors* 2021, 21(9), 3209

Required: accurate time and or phase synchronization of the different receivers



# PNT | Infrastructure and dependency



Highly interdisciplinary skills needed

INCREASING QUANTUM DEMANDS!

Credit: *Credit: ASPIN Laboratory at UC Riverside*

# **PNT needs** | problems and solutions

## **Reality**

- ✓ Trained physicists who don't get what engineers talk and vice versa!
- ✓ Time investment for initial training & understanding
- ✓ Possible shift to another sector after initial training
- ✓ High demand for quantum engineers/physicists (quantum computers, quantum communication etc)

## **Vs**

## **Actual need**

- ✓ Young graduates with an interdisciplinary training in PNT, having basics in electrical engineering, quantum physics, statistics, basics of navigation, timing and frequency skillsets.... Etc
- ✓ Young minds and actionable hands
- ✓ PhDs; Masters; Technicians
- ✓ Save first years in training
- ✓ High retention rate of employees



# PNT needs | problems and solutions

## What PNT industry need?

Skilled manpower who can solve PNT problems from engineering challenges point of view; overview of a physicist, but engineering guy!

**Academic institutions need to develop interdisciplinary education centers focused to train PNT and Quantum related fields...**

### Core competence in one field with PNT knowledge & skillsets

Physics (EM, quantum, optics) & statistics

PNT basics:  
Oscillators, atomic clocks, GNSS, communication etc

Electronics (analog & digital), signal analysis etc

**As a first of its kind approach, UA has initiated efforts towards PNT training!!**

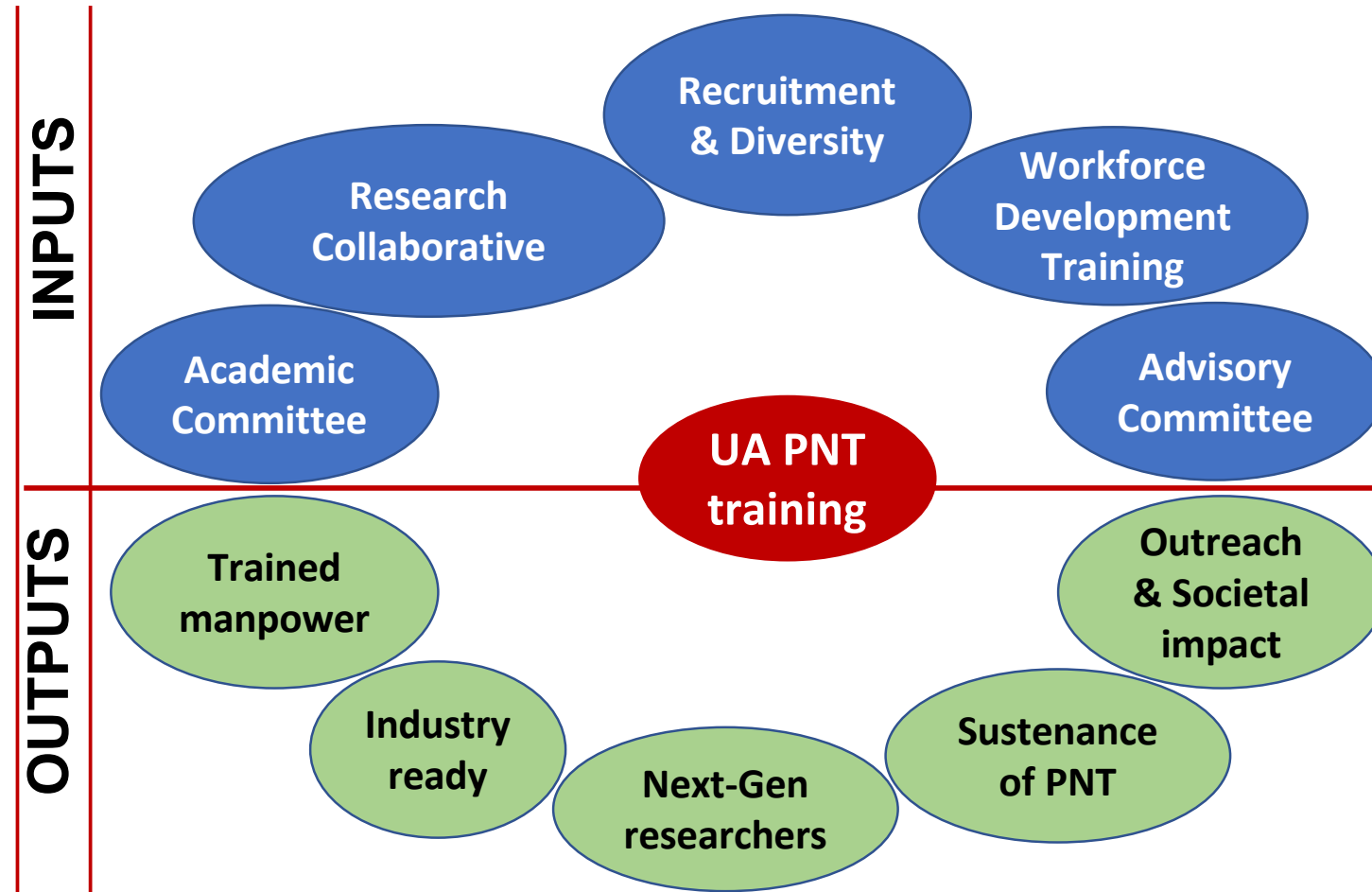


# PNT Center at UA | UA PNT solution

Immersive, Broad-based, Interdisciplinary: *NRT Program*

**ACCEPT: Alabama Collaborative for Contemporary Education in Precision Timing**

NSF support



# PNT Center at UA | UA PNT solution

## Immersive, Broad-based, Interdisciplinary: *Graduate (PhD, MSc ) Program*

- Disciplinary base, interdisciplinary curriculum
  - Specialization degrees in Physics, ECE currently available.
- Stand-alone Graduate Program is planned

	Electrical Engineering	Physics	Mathematics
Classroom Training	Digital Control Systems Sensor Networks Quantum Well Electronics and Devices Solid State Devices	Statistical Physics Electromagnetic Theory Classical Dynamics Quantum Mechanics	Stochastic Processes Statistical Methods for Applied Research Mathematical Statistics Design of Experiment
Tech Immersion	Special Topics in Precision Timing Applications Communications Digital Systems Design	Digital Electronics and Computer Interfaces Research Techniques in Precision Timing Advanced Laboratory in Precision Timing	

# PNT Center at UA | Training Skillsets

## Immersive, Broad-based, Interdisciplinary: *Certification Program*

- Training the manpower from industry
- Remote learning

Course content
Introduction to Precision Timing and Applications (offered Fall semesters only)
Introduction to Scientific Computing and Problem Solving
Digital Electronics & Signal processing
Noise models and their role in atomic clocks and GNSS (offered Spring semesters only)
PNT hands-on Laboratory
Elective 1: Quantum Mechanics
Elective 2: Machine Learning
<b>TOTAL 15 CREDIT HOURS</b>



# **PNT Center at UA** | Training Skillsets

**Immersive, Broad-based, Interdisciplinary: *Certification Program***

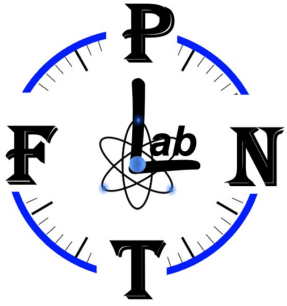
Additional features of the certification & Graduate program

- ✓ Expert talk on PNT topic once every two months
- ✓ Overview to industry and government labs in PNT
- ✓ Exposure to PNT opportunities and outreach (academia & industry)
- ✓ Bridging applications in other diverse fields



# PNT Center at UA

Establishment | Legacy of H-Masers!



## The PNTF Lab

<https://PNTFLab.UA.edu>

*Investigate the basic precision physics principles to implement & develop niche timing, frequency & navigation devices.*

Physics faculty:



Dr. T. N. Bandi, PI



Dr. A. J. Hauser

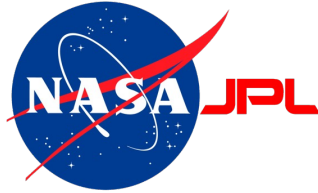


Dr. P. R. LeClair



Dr. S. V. Gleyzer

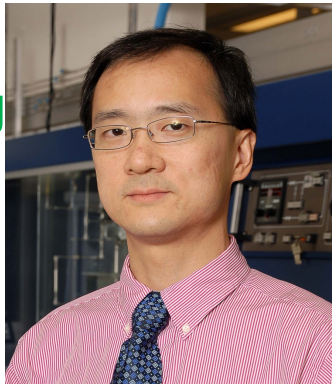
Support:



MICROCHIP



Engineering faculty:



Dr. P. Kung



Dr. M. Rahman



Dr. T. J. Freeborn

External:



B. Owings, Microchip



WHERE LEGENDS ARE MADE

WSTS - 2023, March 13 - 16, Vancouver, BC





## Tide Timing Clock Club {T<sup>2</sup>C<sup>2</sup>}

- ❖ University registered entity focused on hands-on training for undergrads in PNT!
- ❖ Since January 2022
- ❖ Presently 13 active members
- ❖ Weekly meetings & interactions
- ❖ Hands-on mini-Lab-tasks

### Present activities:

- ✓ MASER refurbishment
- ✓ Kalman filter, timescale
- ✓ Lab thermal studies
- ✓ Laser characterization
- ✓ Navigation basics



# Collaboration & Benefits | Your Inputs!!

## What do we need?

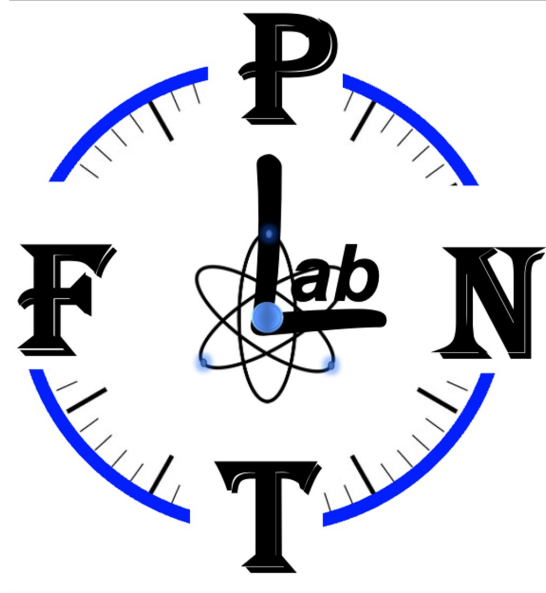
- **Inspiration!**
  - What do you need? Who do you need?
  - How can we serve the PNT community?
- **Communication**
  - Needs change frequently
  - Academic centers are flexible – new directions are welcome.
- **Partners for Immersive Education**
  - Internships at all levels, including UA co-op opportunities
  - Joint Research (on- or off-site available)
  - Teach and train on your equipment in our lab courses



## **OUTLOOK**

- ❖ PNT Center dedicated for students training and related research
- ❖ Industry sponsored masters and PhD programs
- ❖ Your raw-manpower, your funds, our training and shaping a skilled-manpower
- ❖ Sustenance and shaping the future of PNT-F field
- ❖ Enabling the possibility towards... Quantum 3.0?

# Outlook | Thank you!



<https://PNTFLab.ua.edu>

Contact: [tbandi@ua.edu](mailto:tbandi@ua.edu)

- ✓ Excellent team of collaborators with diverse expertise within UA
- ✓ Industrial collaborations
- ✓ Collaborations and links with Government labs