

# Coordinating Panel for Advanced Detectors (CPAD) Efforts and FCC Needs

<https://cpad-dpf.org/>

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# Caveat #1

I'm going to be “wearing multiple hats” during this talk



CPAD co-chair



RDC 1 co-coordinator  
&  
DRD2 WP Leader



Instrumentation  
Enthusiast



Opinionated  
physicists

I'll do my best to clarify the positions I'm expressing as I go through the talk

# Caveat #2

There is much about the FCC which you already know about and don't need me to reiterate beyond what was expressed during the last three days

- **The science case is compelling and well endorsed** at the highest levels in the US (P5 report) and in Europe (ESG)
- The **required technology development to realize the FCC is great** and ever being focused and refined
- The **funding environment is going to be difficult** over the next few (critical) years
  - See Regina's talk on Wednesday
- **The need for US involvement is important**
  - This critically includes training and support of early career scientists in all aspects of the project (including instrumentation R&D)
  - This is where CPAD can be useful

**Ambitious projects create the scientific pull for innovation**

**CPAD/RDCs can help the community generate and mature these ideas within the broader HENP community**

# CPAD and the HENP Community

A not uncommon characterization of the HENP Community often brings to mind an image of a herd of cats

I think this image is even more true when it comes to instrumentation R&D and detector development

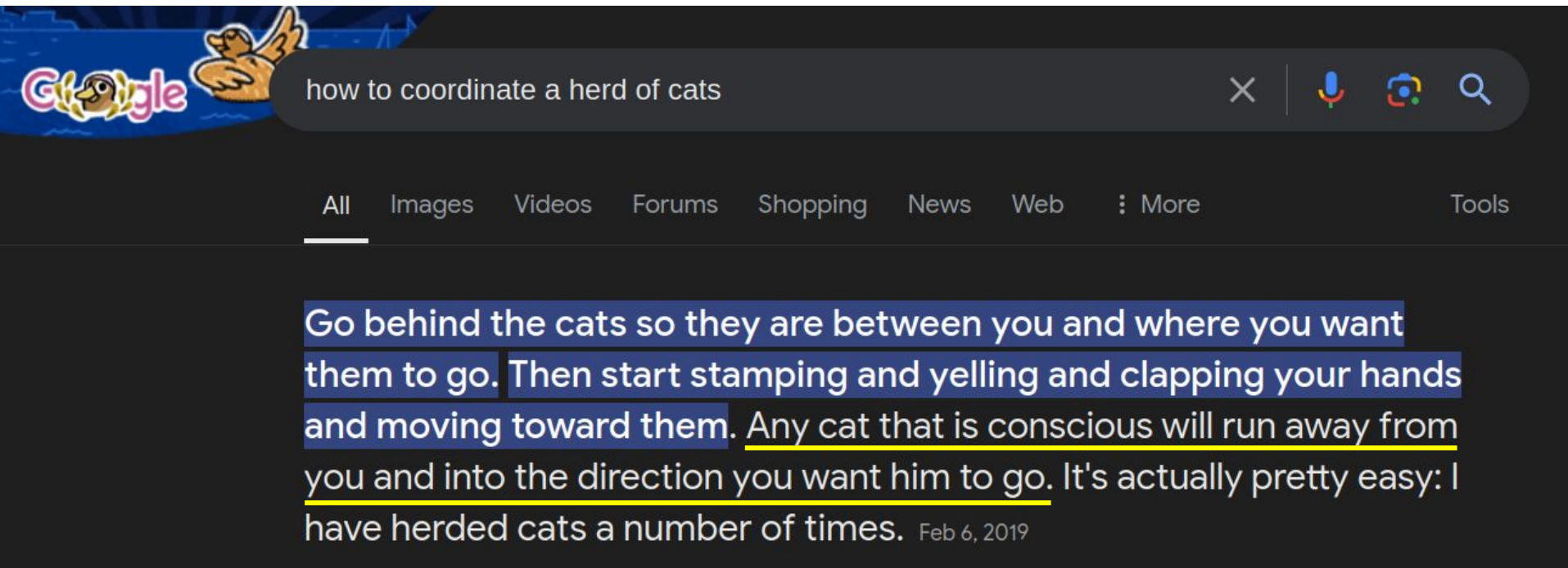




And the sisyphian task of trying to coordinate them is often seen as trying to “herd” cats

Which wikipedia quotes as: **“denoting a futile attempt to control or organize a class of entities which are inherently uncontrollable”**

# So of course, I just ask Google how to do this....



# Herding cats to a goal

So if the goal is to build to build a next-generation collider and experiment, than CPAD can play a role by helping coordinate and communicate ongoing work across all efforts (e.g FCC), can help identify and promote technologies which lead to next generation detectors (fast timing, precision calorimetry, high granular tracking, radiation hardness, etc...) and potential breakthroughs in physics



# The American Physics Society (APS) and Division of Particles and Fields (DPF) Coordinating Panel for Advanced Detectors (CPAD)

## CPAD Mission and Goals:

- The Coordinating Panel for Advanced Detectors (CPAD), seeks to promote, coordinate and assist in the research and development of instrumentation and detectors for high energy physics experiments.
- By helping to coordinate the development of both evolutionary and transformative detector instrumentation across the national laboratories and with the university community, CPAD works to ensure the future of high-energy physics experiments.

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***It is out of these aspects of CPAD's mission and goals and the work of the Snowmass process which the concept of the formation of Research and Development Collaborations (RDC's) within CPAD was born***

# Snowmass IF Recommendations

- IF-1** Advance performance limits of existing technologies and develop new techniques and materials nurture enabling technologies for new physics, and scale new sensors and readout electronics to large, integrated systems using co-design methods.
- IF-2** Develop and maintain the critical and diverse technical workforce, and enable careers for technicians, engineers and scientists across disciplines working in HEP instrumentation, at laboratories and universities.
- IF-3** Double the US Detector R&D budget over the next five years, and modify existing funding models to enable R&D consortia along critical key technologies for the planned long term science projects, sustaining the support for such collaborations for the needed duration and scale.
- IF-4** Expand and sustain support for blue-sky R&D, small-scale R&D, and seed funding. Establish a separate agency review process for such pathfinder R&D, independently from other research reviews.
- IF-5** Develop and maintain critical facilities, centers and capabilities for the sharing of common knowledge and tools, as well as develop and maintain close connections with international technology roadmaps, other disciplines and industry.

# These are where the CPAD RDC's come in

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# Some critical aspects from the P5 report

The particle physics community has identified the need for stronger coordination between the different groups carrying out detector R&D in the US. We strongly support the R&D Collaborations (RDCs) that are being established and will be stewarded by CPAD, the Coordinating Panel for Advanced Detectors, overseen by the APS/DPF. The RDCs are organized along specific technology directions or common challenges, and aim to define and follow roadmaps to achieve specific R&D goals. This coordination will help to achieve a more coherent detector instrumentation program in the US, and will help to avoid duplication while addressing common challenges. International collaboration is also crucial, especially in cases where we want to have technological leadership roles. Involvement in the newly established Detector R&D Groups at CERN is encouraged, as are contributions to the design and planning for the next generation of international or global projects. Targeted future collider detector R&D in particular, such as for Higgs factories or a muon collider, is covered in Section 6.5.

The RDC's are in the P5 report as is participation in the CERN based Detector R&D (DRD's)

**Area Recommendation 6: Increase the budget for generic Detector R&D by at least \$20 million per year in 2023 dollars. This should be supplemented by additional funds for the collider R&D program.**

**Area Recommendation 7: The detector R&D program should continue to leverage national initiatives such as QIS, microelectronics, and AI/ML.**

# Principal Ideas behind the RDCs

Detector R&D in many different technology areas is essential to realize many of the future planned experimental efforts spanning all of the frontiers in High Energy / Nuclear Physics

Much of the efforts needed require **collaboration** and **coordination** in order to realize the technologies required

- **Collaboration**: The required expertise/resources/new ideas often live within multiple people, institutions, labs and only by bringing these pieces together can we hope to realize the technological challenges
- **Coordination**: We live in a resource limited funding environment and so we need efforts to be coherent, minimize duplication, and to build off of progress happening elsewhere (both in other technologies and in other places)

# Principal Ideas behind the RDCs

Detector R&D in many different technology areas is essential to realize many of the future planned experimental efforts /  
Nuclear Physics

## Collaboration

Where the RDC's can work to identify needed R&D, work together to assemble proposals, and aid in the execution of the work

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## Coordination

This is what CPAD is meant to help provide and why these collaborations are being formed within our structure/charge

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# R&D Collaborations (RDCs) - Status

| RDC | Topic                                 | Coordinators                          |
|-----|---------------------------------------|---------------------------------------|
| 1   | Noble Element Detectors               | Jonathan Asaadi, Carmen Carmona       |
| 2   | Photodetectors                        | Shiva Abbaszadeh, Flavio Cavanna      |
| 3   | Solid State Tracking                  | Douglas Berry, Sally Seidel           |
| 4   | Readout and ASICs                     | Mitch Newcomer, Lorenzo Rota          |
| 5   | Trigger and DAQ                       | Zeynep Demiragli, Alexander Paramonov |
| 6   | Gaseous Detectors                     | Bob Azmoun, Sven Vahsen               |
| 7   | Low-Background Detectors              | Daniel Baxter, Luara di Vacri         |
| 8   | Quantum and Superconducting Detectors | Caleb Fink, Rakshya Khatiwada         |
| 9   | Calorimetry                           | Marina Artuso, Minfang Yeh            |
| 10  | Detector Mechanics                    | Andy Jung, Eric Anderssen             |
| 11  | Fast Timing                           | Roger Rusack, Matt Wetstein           |

See [this webpage](#) for details about each RDC

# What will the RDC's do?

## Long term goal:

- **Establish collaborations** which can link together facilities, expertise, people, and experience to tackle technology challenges across HEP/NP
  - This work has started and can be seen within the RDC's themselves as well as the links between many RDC's and CERN DRDs
- **Facilitate new funding** mechanisms for R&D related to a specific technology area which will take place as part of the collaborations' activities
  - The 2026 NOFO included Multi-institutional team applications for HEP Detector R&D
  - CPAD and the RDC's have been involved in helping coordinate responses to funding calls (e.g. Quantum, Microelectronics, Comparative review, etc)
- Work with the CPAD executive committee, ECFA DRDs, and the broader R&D community to **foster a collaborative, supportive, and coordinated environment for new ideas, blue sky efforts, and non-project specific R&D**

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*You might ask yourself, what does this aspect of the RDC's mean....*

The background of the slide is a photograph of a bright blue sky filled with large, puffy white cumulus clouds. The clouds are more concentrated in the lower half of the image, while the upper half is a deeper blue with some wispy clouds.

# *Blue Sky R&D*

**What do we mean here...**

The background of the slide is a photograph of a bright blue sky filled with fluffy white clouds. The clouds are more concentrated in the lower half of the image, creating a sense of depth.

*We typically use*

*“I know it when I see it”*

*which isn't great...*

# Thinking about “Blue Sky”

- There is this “slippery slope” between what some call “Blue Sky” and what people call “Project Specific” which makes defining what we mean difficult
- A few points on this
  - Just because R&D is “Project Specific” doesn’t mean it it won’t be transformational!
    - Sometimes solutions to one persons problems end up being the solution we didn’t know we were looking for!
  - Just because R&D is “blue sky” doesn’t mean it won’t be applied to a project
    - If the idea is ends up being as good as one hopes, it could change the way we build detectors



# Thinking about “Blue Sky”

- Where your idea lives on this mountain can be somewhat subjective and is often debated
- CPAD and the RDC’s aim to work with proponents to target the most “blue-sky” version of your ideas
- I expect that much of the required instrumentation R&D needed for the FCC is higher on the mountain and “in common” with other efforts than one might initially think



# So what do we mean (a loose and untested definition)

*And I'm sure many will disagree with this attempt to define it....*

## **Blue Sky R&D should have some number of these attributes**

- The work has a speculative aspect which requires a group of people performing work to test the hypothesis that the proposed technology/technique/sensor/method/approach will address with the possibility of failure
  - “High Risk”
- The goal of the research, if successful, should be a new technology/technique/sensor/method/approach which would change the way we currently do some aspect of instrumentation in HEP
  - “High Reward”
- The project brings together different domains of expertise in a new or novel way
  - “Cross-cutting”
- This work can be in a direction where the immediate "real-world" applications are not apparent right now, but have a notional direction which seems promising and unexplored
  - “Basic Research”

# My thoughts on blue-sky R&D and the FCC

- Often to work going on in instrumentation R&D (and specifically in applications like the FCC-ee) have some ambitious and difficult end goal.
  - That end goal may be motivated by the requirements set down by a specific project
- However, I believe with some thought and broader context that R&D may actually be a solution to other larger instrumentation goals.
  - CPAD and the RDC's can help find the most blue-sky version of that idea
- Moreover, if the difficult and ambitious end goal is shared more broadly, new and yet unconsidered ideas may be lying in wait



The process of finding the most blue-sky version of an idea and sharing the ambitious end goal with the broader community is where engagement with CPAD and the FCC efforts can be the most fruitful

# What will the RDC's **NOT** do?

The RDC's will **NOT**:

- **Discourage single/small team efforts in R&D**
  - We still need for individual PI's to be able to work in their labs on their favorite ideas and leave room for innovation and unexpected solutions
- **Break up existing organizations / structures**
  - We already have communities within HEP/NP which coordinate on specific technological challenges (e.g. HEP-IC) and we want to utilize/leverage these efforts and communities to help make the CPAD-RDC's successful
- **Discourage project specific R&D**
  - There is some R&D which will/has reach(ed) a level of maturity that it is time to realize it for a specific implementation and the RDCs should encourage this transition from generic to specific R&D

# What have the RDC's done from 2024 - now

- **For the 2024 DOE Comparative Review, CPAD and the RDC's aimed to put forward a small number of university lead, multi-institutional proposals focused on generic "blue-sky" R&D**
  - To this end, we opened up submission of community lead "White Papers" which outline proposals for such consortia. These white papers were used to help CPAD coordinate and promote groups intending to submit to the DOE Comparative Review in September 2024
- **For 2025 DOE Comparative Review CPAD RDCs undertook a mini-Basic Research Needs (BRN) process.**
  - Each RDC articulates the R&D priorities with the associated community, produces a list of handful priorities in a consistent format. Cross-RDC priorities are identified and listed separately. A document combining all RDC priorities will be made available to the community and posted online to provide a citable reference.
  - [Link to the document](#)

# CPAD Mini-BRN

Coordinating Panel for Advanced Detectors

## RDC R&D Priorities CPAD 2025

Contacts: Jonathan Asaadi (CPAD vice-Chair), Jinlong Zhang (CPAD Chair)

### RDC1: Noble Element Detectors

- **RDC1-WP1: Enhance and combine existing readout modalities**

New ideas in charge detection (e.g. pixels, extreme low threshold detection, charge gain, ion detection); new ideas in light detection (e.g. new technologies, geometries, materials, wavelength shifting).

- **RDC1-WP2: New modalities for signal detection**

Going beyond the current paradigm just collecting electrons and photons (e.g. meta-stable fluids, micron-scale tracking, combined multimodal sensors); enhancement in the electronics and readout of the detectors (e.g. photonic readout solutions, new/enhanced architectures at the front-end, artificial intelligence/machine learning inside the detector).

- **RDC1-WP3: Challenges in scaling technologies**

Scaling of purification, radiopurity, doping, high voltage, and other target challenges (e.g. large-scale purification, removing radioactive contaminants).

While we are still awaiting the outcome of the comparative review for 2025, initial feedback from the program manager and the participants was that this document was helpful in demonstrating alignment with top-level US instrumentation needs

### Cross-RDCs Topics

- **cRDCs-WP1: Intelligence in the front-end electronics**

Integration of artificial intelligence / machine learning (AI/ML) algorithms for on-chip triggering and/or data-reduction capabilities. Technologies include smart pixel technology, embedded Field Programmable Gate Arrays (eFPGA), anomaly detection systems, and unconventional computing methods. [RDC1, RDC3, RDC4, RDC5, RDC6, RDC9]

- **cRDCs-WP2: Timing distribution with picosecond synchronization**

Precision timing protocols and distribution systems enabling sub-picosecond synchronization over large-scale detector networks for TDAQ applications (1 ps over 1 km). [RDC3, RDC4, RDC5, RDC6, RDC9, RDC11]

- **cRDCs-WP3: Monolithic Active Pixel Sensors**

Novel Monolithic Active Pixel Sensors (MAPS) with a focus on improving timing (few ns and below) and spatial resolution (sub-10 $\mu$ m). This includes exploring novel materials and technologies (CMOS and beyond) and novel readout approaches. [RDC3, RDC4, RDC9]

# RDC's in 2025

The RDC's also tried to engage with groups to help them with their proposals and addressing common problems / concerns which arise during the review process. ([You can find the full talk here](#))

- **A small number of PI's were willing to share their reviews from the comparative review process**
  - These include proposals which were funded and ones which were not funded
  - Some were willing to send us the reviews directly, some sent us their own takeaways
  - Many asked for the reviews to remain anonymous
- **One key takeaway:**
  - Overall, the CPAD/RDC whitepaper/endorsement process in 2024 did not appear in the written reviews (for better or worst) which I had access to and thus we don't make a statement on their overall impact on the outcome of the proposals
- **The identified common points of feedback**
  - Clear, specific objectives & success metrics
  - Justification with quantitative evidence
  - Risk awareness and alternatives
  - Programmatic alignment
  - Budget clarity & cost-to-impact narrative

# CPAD 2026

Instrumentation and detector R&D workshop  
for high energy physics

Organized by the University of Washington and  
Pacific Northwest National Laboratory  
cpad-dpf.org



**CPAD Conference for 2026 is open for  
registration and abstract submission**

<https://indico.global/event/17230/>

Very good opportunity (especially for  
early career scientists) to come and tell  
the broader instrumentation community  
about the R&D you are engaged in (and  
socialize why this R&D is important to  
FCC and beyond)

**Where CPAD and the RDC's will go  
next is an important topic for this  
conference**

**20–23 October 2026**

University of Washington · Seattle, WA

Call for abstracts open  
Registration open  
[indico.global/event/17230](https://indico.global/event/17230)  
[cpad2026-loc@gmail.com](mailto:cpad2026-loc@gmail.com)



# The CPAD RDC's and the CERN based DRDs

Figuring out how to maximize the potential coordination and collaboration between the DRD's and RDC's remains a priority/goal for CPAD, [albeit a goal without a concrete model of what success looks like](#)

*Note: I showed this slide last year, but unfortunately I don't think the circumstances have changed much*

## Complicating factors:

- Many of the DRD's have narrowed their focus to Future Circular Collider (FCC) based activities
  - CPAD RDC's have been given a mandate to focus on more generic/blue-sky R&D
- Timelines and requirements for funding and resources has been constructed very differently
  - CPAD RDC's have kept a much more "light-weight" approach
- Timezone and the ever growing number of meetings to attend also makes maximum engagement in both places difficult

I do believe if we could develop a single concrete project/idea/collaboration which satisfies the RDC requirement of being "blue-sky" and the DRD requirement of having well defined deliverables and timelines would be a warmly welcome example within the US detector R&D program

# Conclusions

- The US instrumentation community via CPAD is working to form collaborations to tackle the larger detector R&D challenges facing the HENP community
- It is my sincere hope that this can be done in collaboration and harmony with the CERN based DRD's as well as the long term high priority projects identified in the P5 report
  - Identifying key areas of overlap and looking for areas of opportunity will be a big part of this process
    - You have an ally “on the inside” as I am playing a role in the DRD's, CPAD, and the RDC's
- I hope the process can be done without a heavy hand, as the nature of this work is explorative, adaptive, and prone to failure (it wouldn't be R&D otherwise)
  - Instead let us focus on bringing together the world experts to tackle some groundbreaking instrumentation. Let us bring together some of the cutting edge resources, processes, and collaborations to allow us to fulfill what only advances in instrumentation can do:

*“Measure what is measurable, and make measurable what is not so”*

**We stand at a decade of HEP with immense ambition and challenge ahead of us to realize the next generation of facilities, detectors, sensors, and experiments which will light the way to the next major discoveries in physics**

