Polarimeter to Unify the Corona and Heliosphere

PUNCH Mission Overview & Status

Craig DeForest

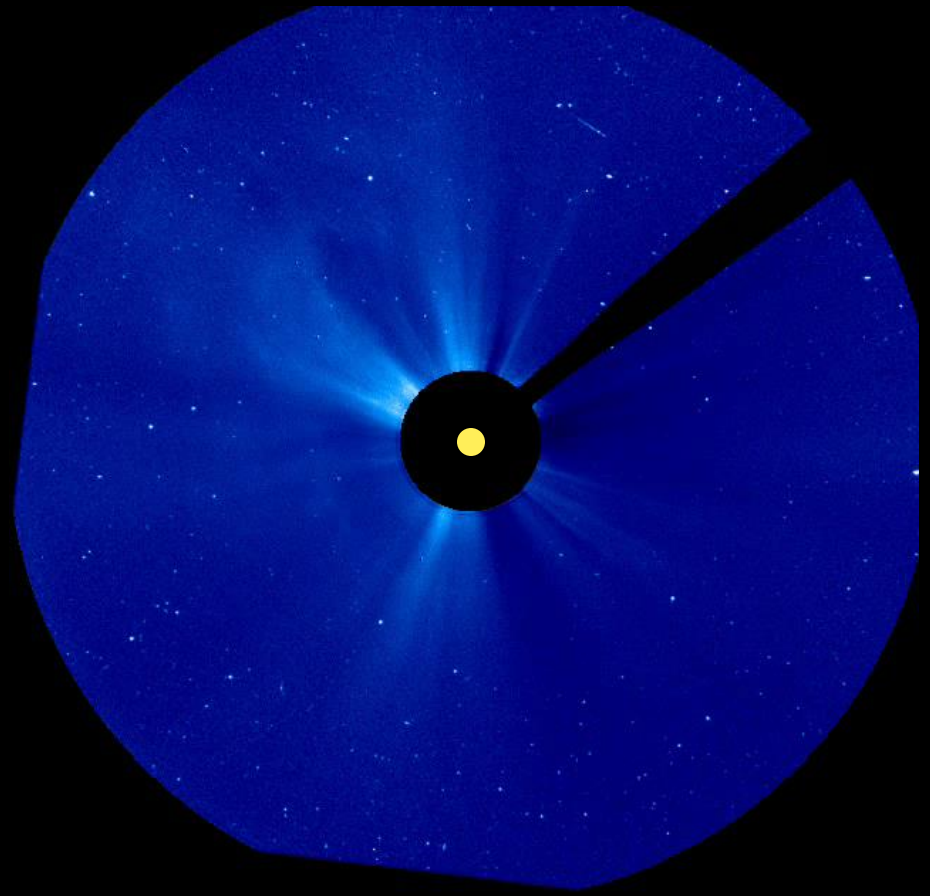
25-Feb-2025

PUNCH-6

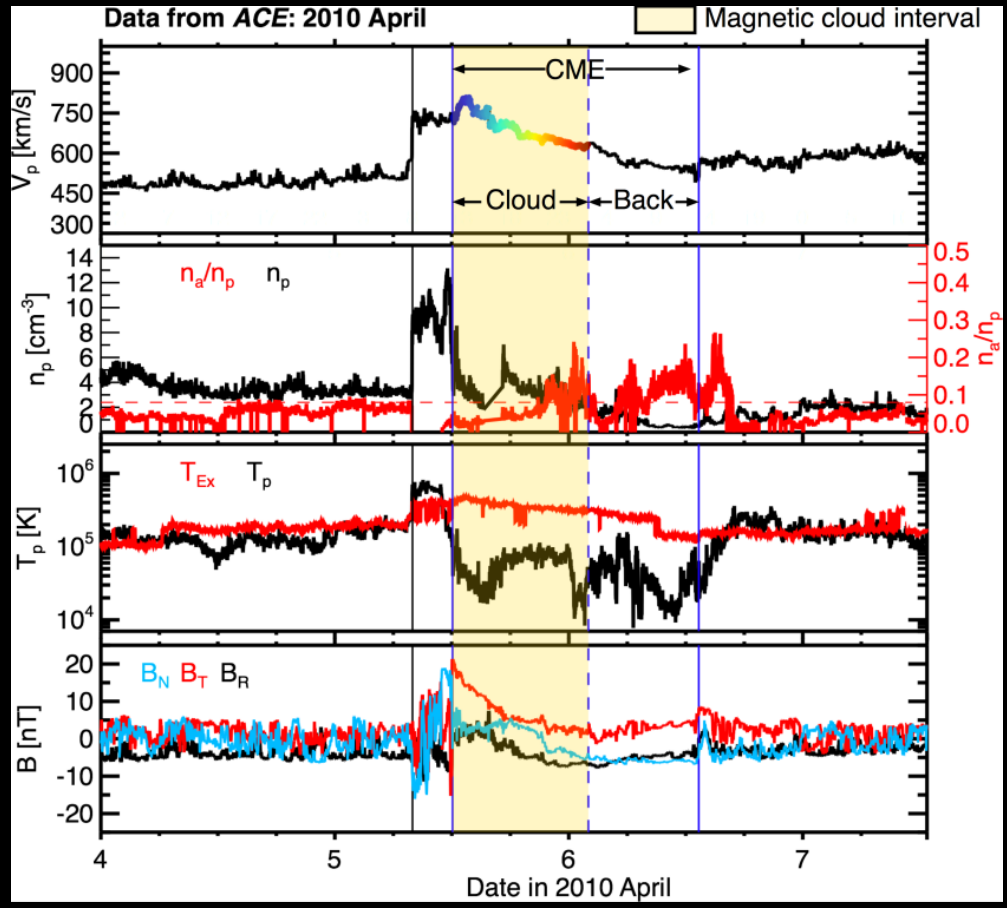
“Ready to Launch”

UNIFYING SOLAR PHYSICS & HELIOSPHERIC PHYSICS

Solar physics studies the Sun and corona, primarily through remote sensing and spectral analysis



Heliospheric physics studies the solar wind in interplanetary space, primarily through in-situ sampling



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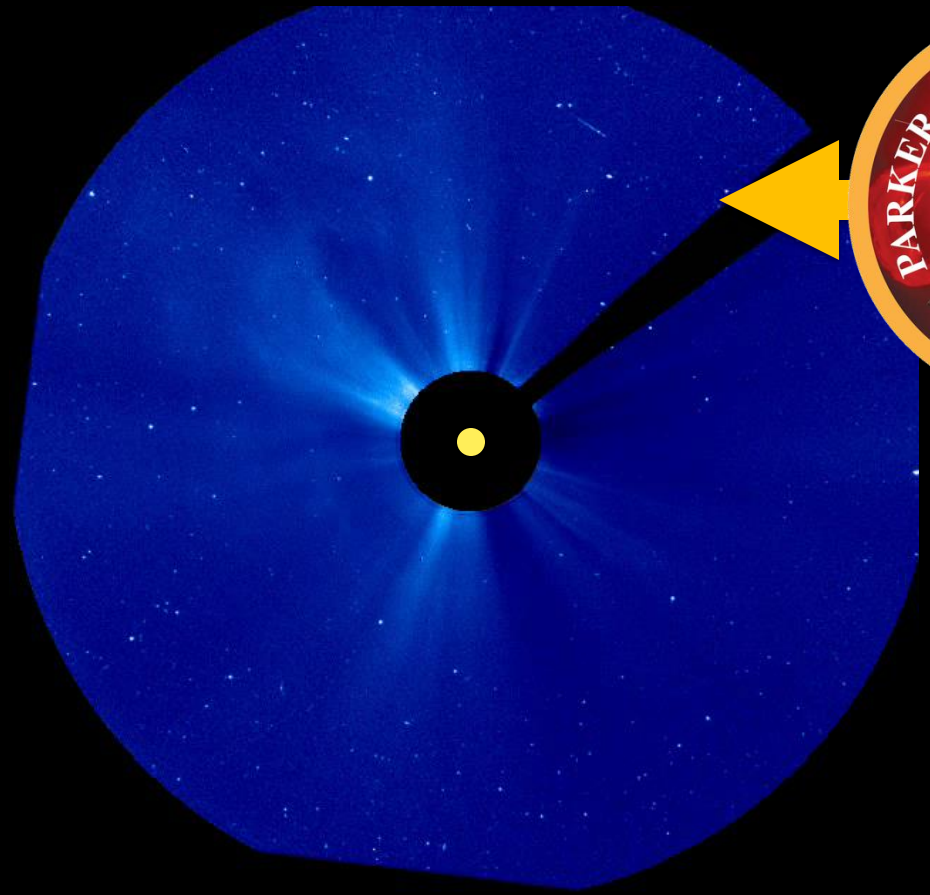

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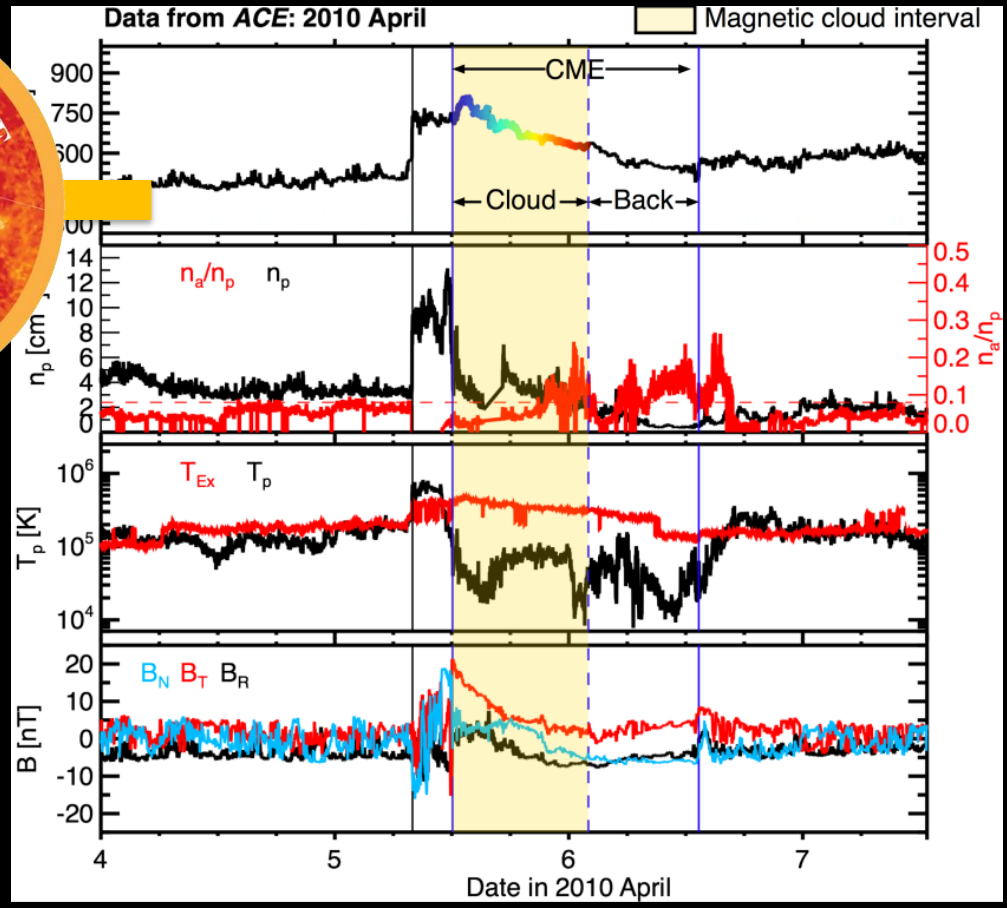

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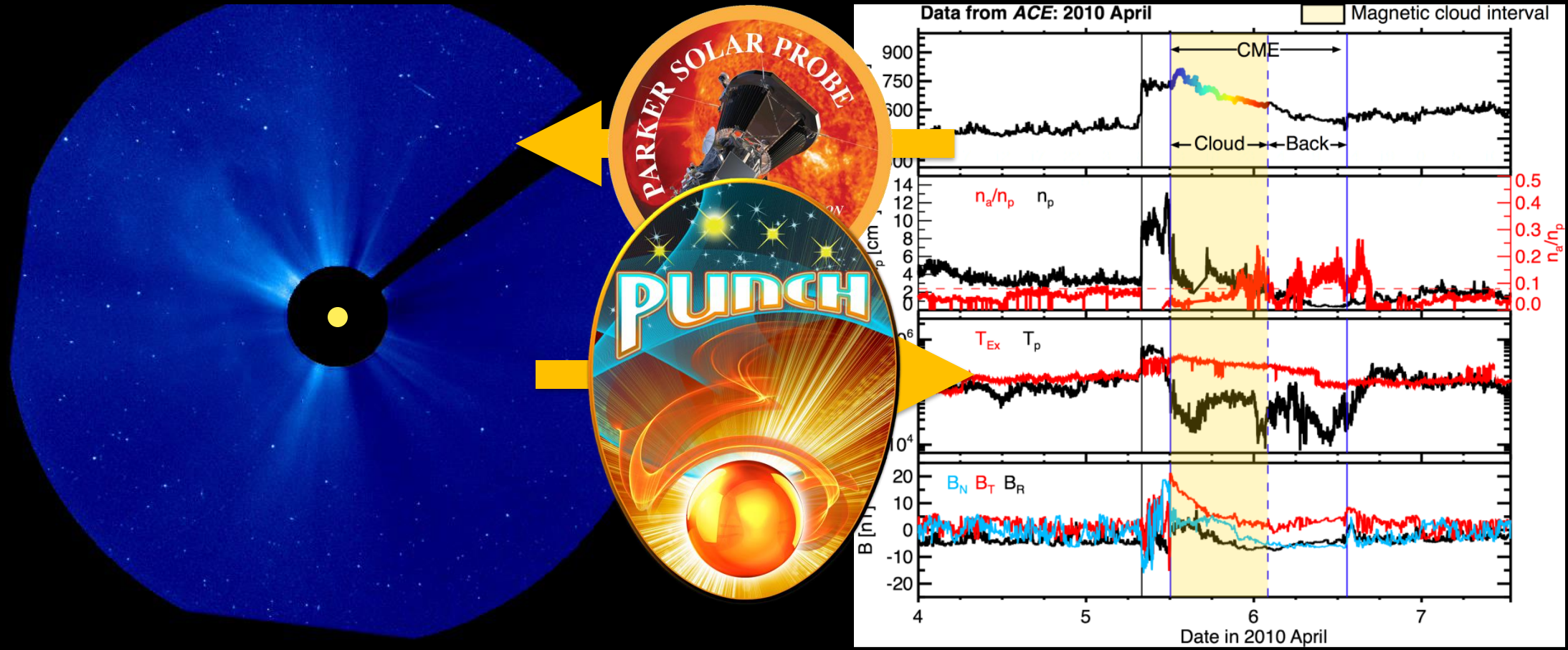


WHAT IS PUNCH?

Scientific Driver: Understanding how the corona gives rise to the heliosphere and solar wind

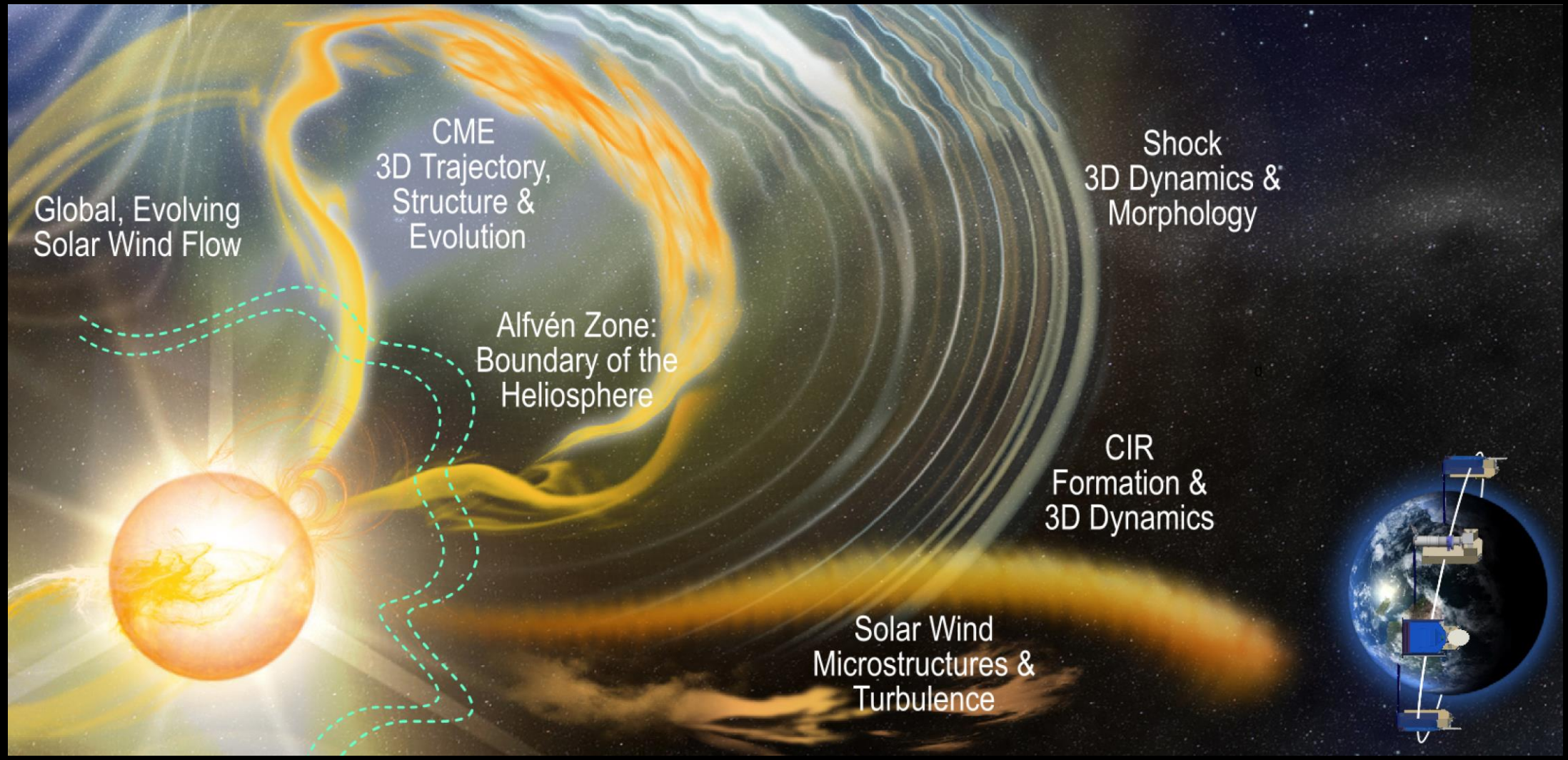
Approach: direct, continuous, 3D imaging of the entire outer corona and inner heliosphere

Measurement: polarized images of Thomson-scattered light

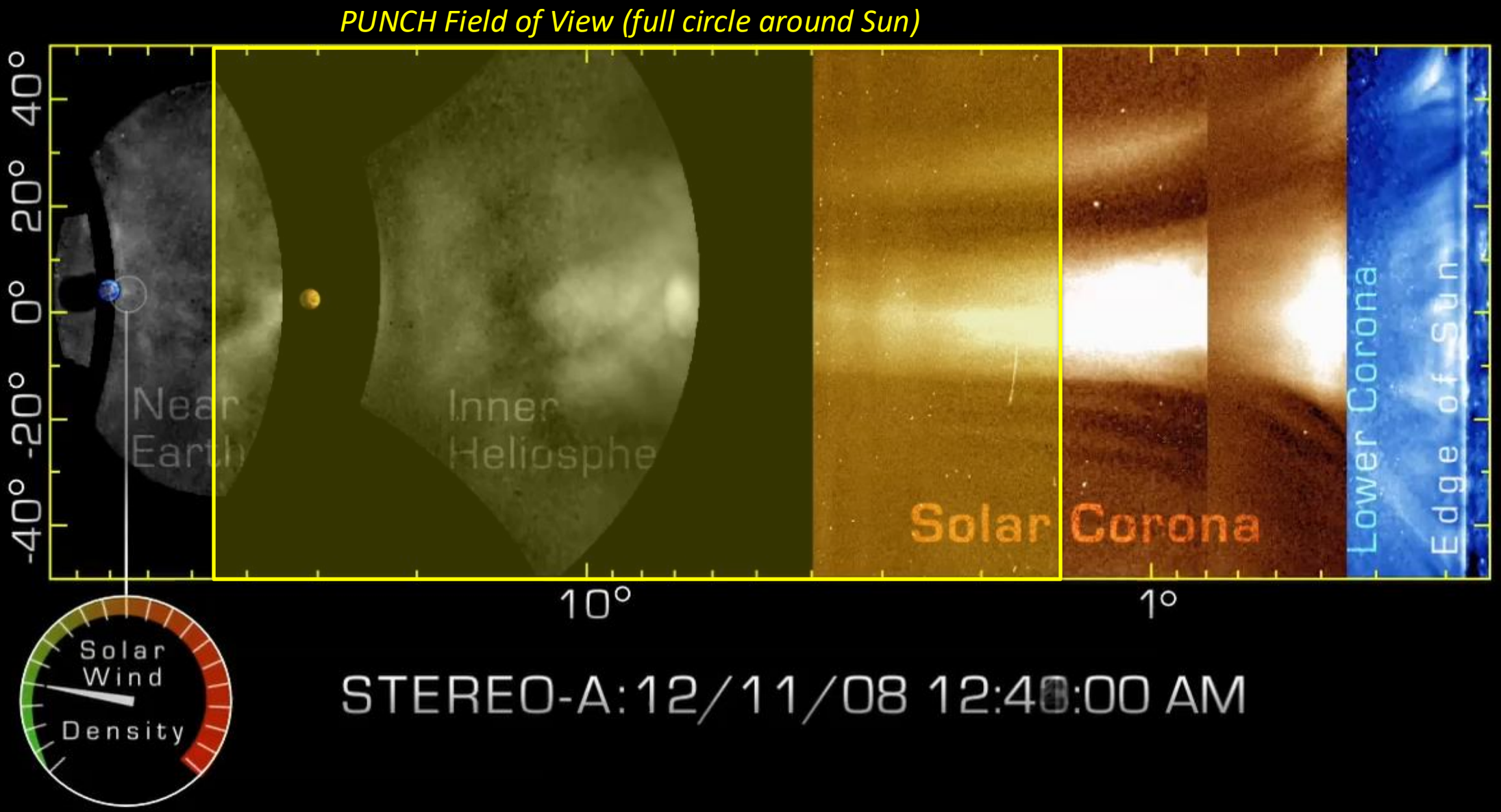
Mission structure:
- four synchronous smallsats
- 650km sun-synchronous 6am/6pm LEO
- two year nominal mission duration

PUNCH science objectives

1. Understand how coronal structures become the *ambient solar wind*
2. Understand the dynamic evolution of *transient structures* in the young solar wind

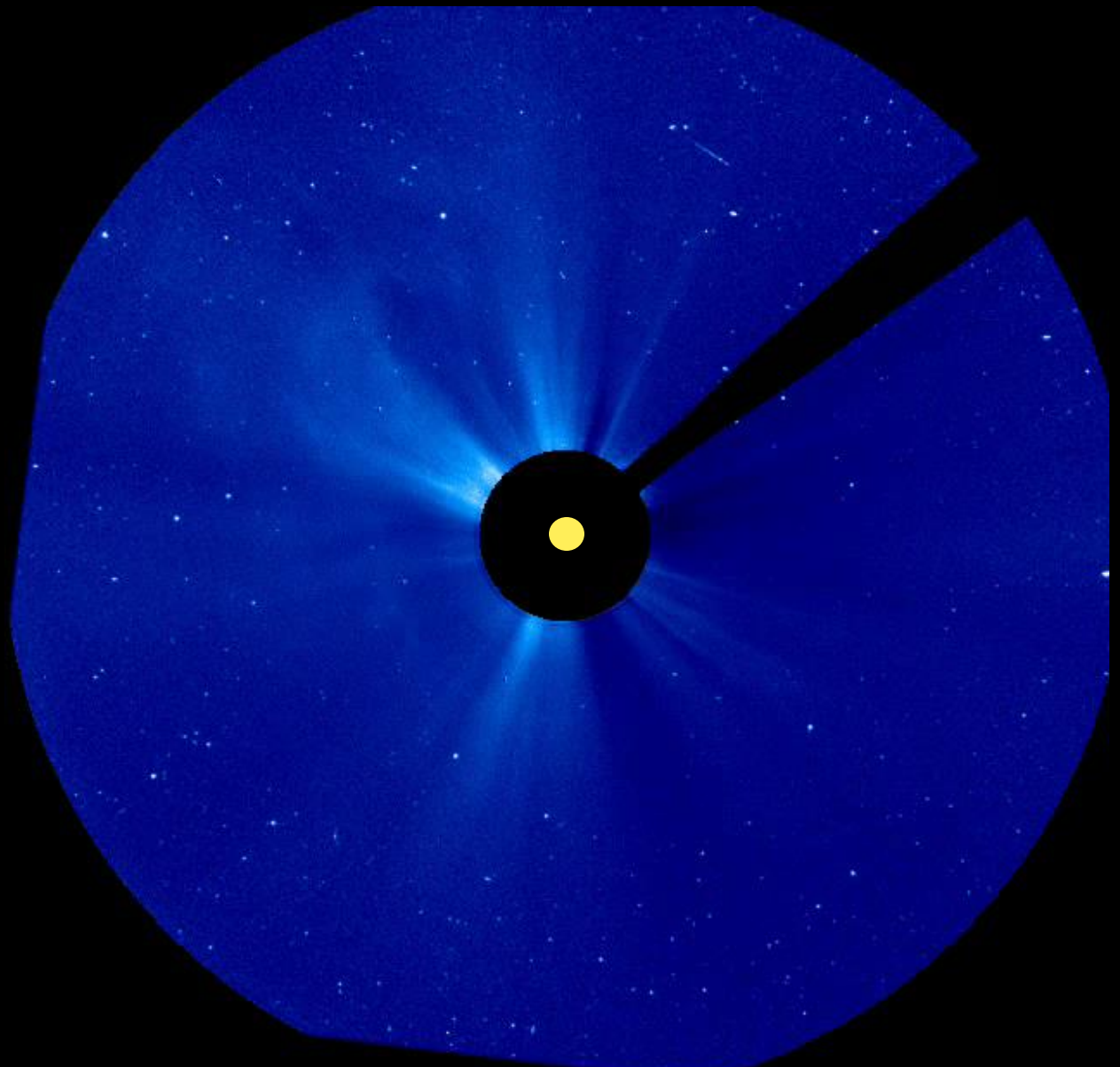


PUNCH WILL IMAGE HOW THE SUN AND EARTH ARE CONNECTED

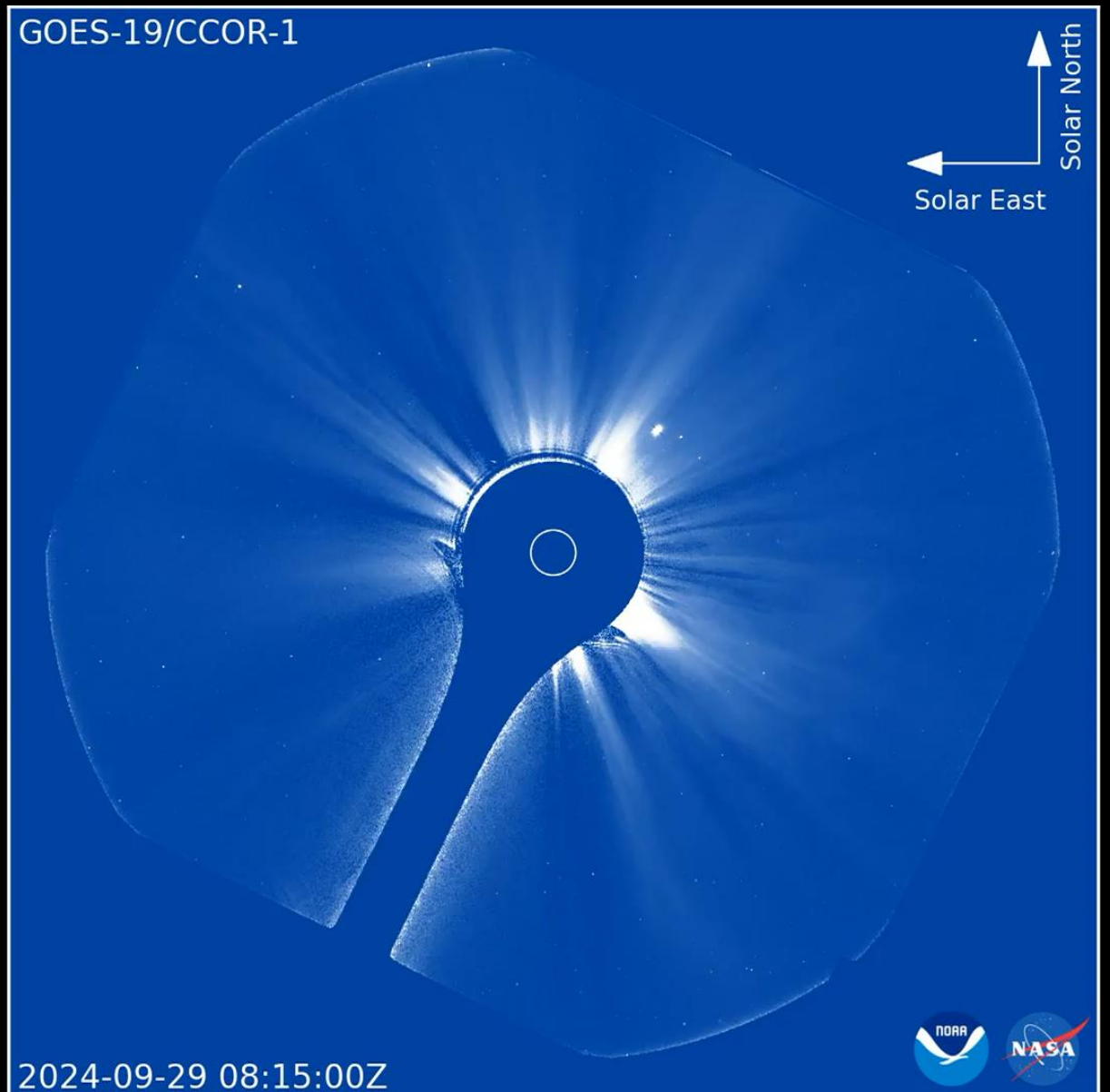


LOW NOISE CHANGES IMAGES MORE THAN YOU THINK

LASCO C-3 (1995-2025?)

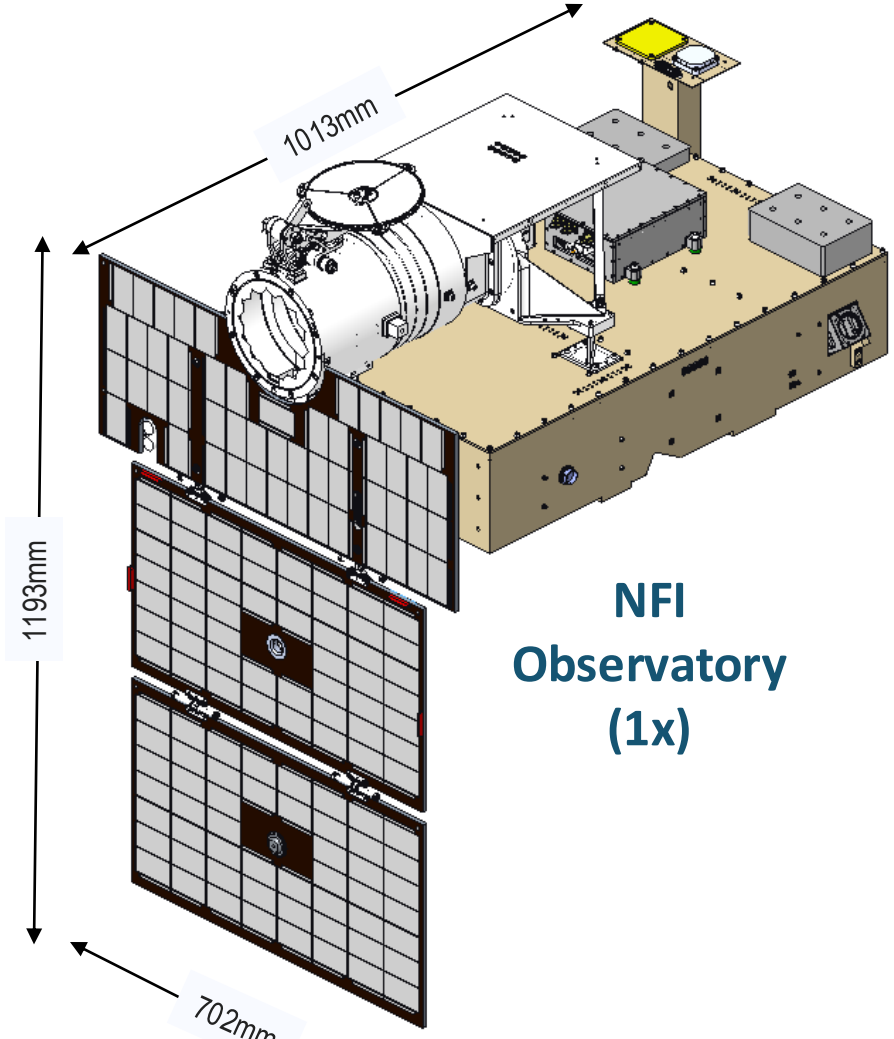


CCOR-1 (2024 - ?)



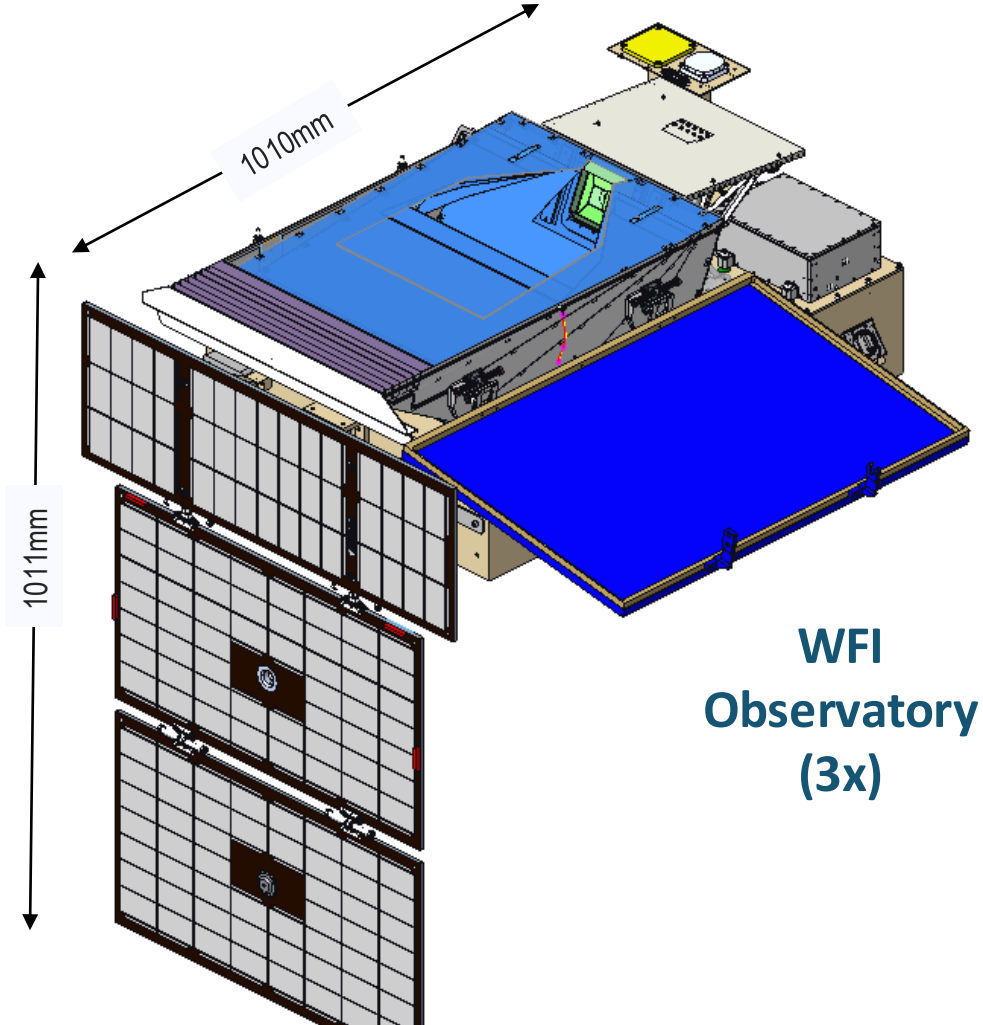
PUNCH Observatories

Narrow Field imager (NFI): Compact Coronagraph design
Naval Research Laboratory



NFI Observatory (1x)

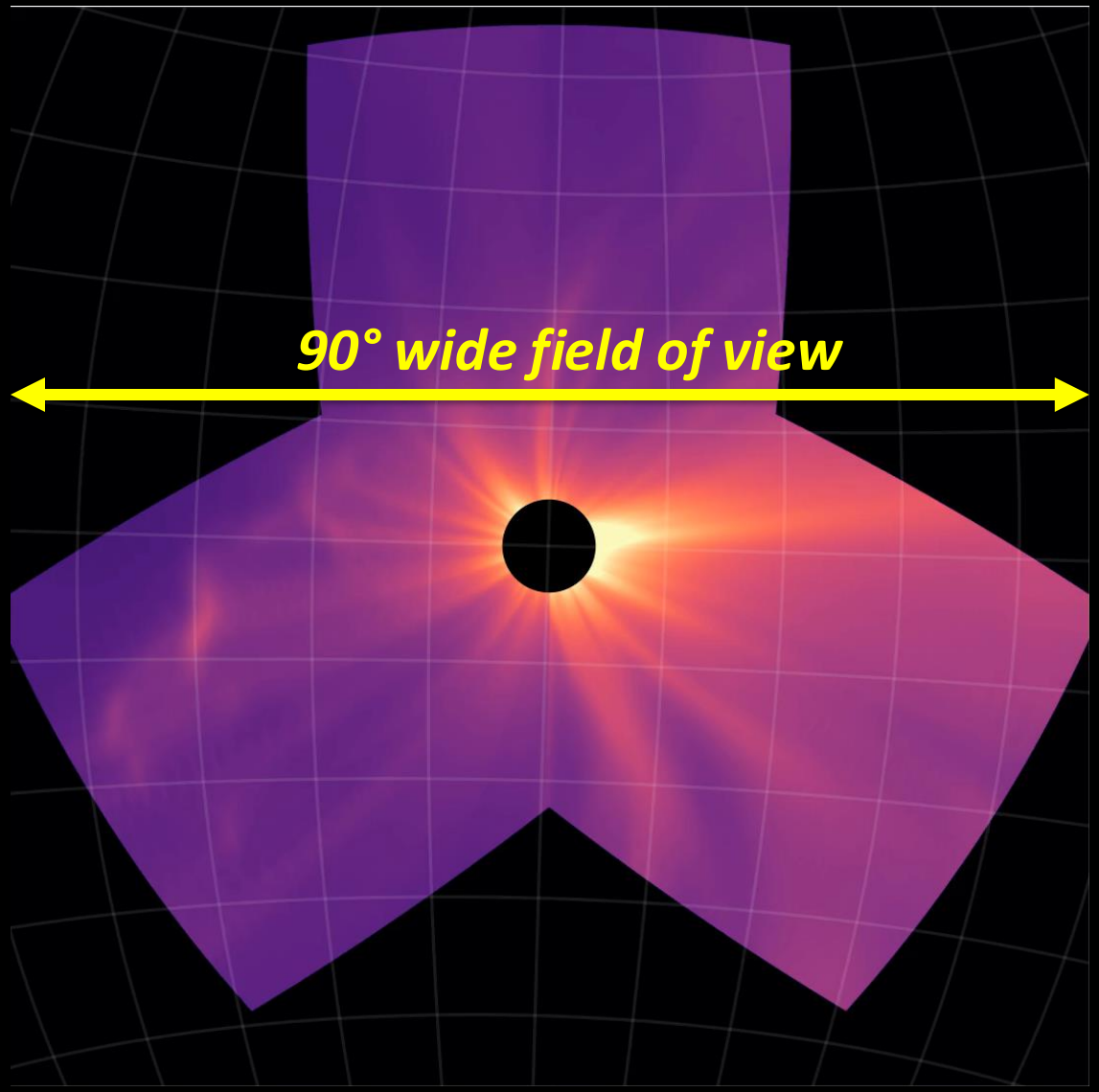
3x Wide Field imager (WFI): Heliospheric Imager design
Southwest Research Institute



WFI Observatory (3x)

Instruments: up next! (Colaninno, Laurent)

PUNCH MERGES IMAGES TO TRACK THE SOLAR WIND, SUN TO EARTH



- Exposures are synchronized and merged.
- Data are images from a single “virtual instrument”.
- PUNCH uses polarization to track space weather (e.g. CMEs) in 3D.

BABY PICTURES!

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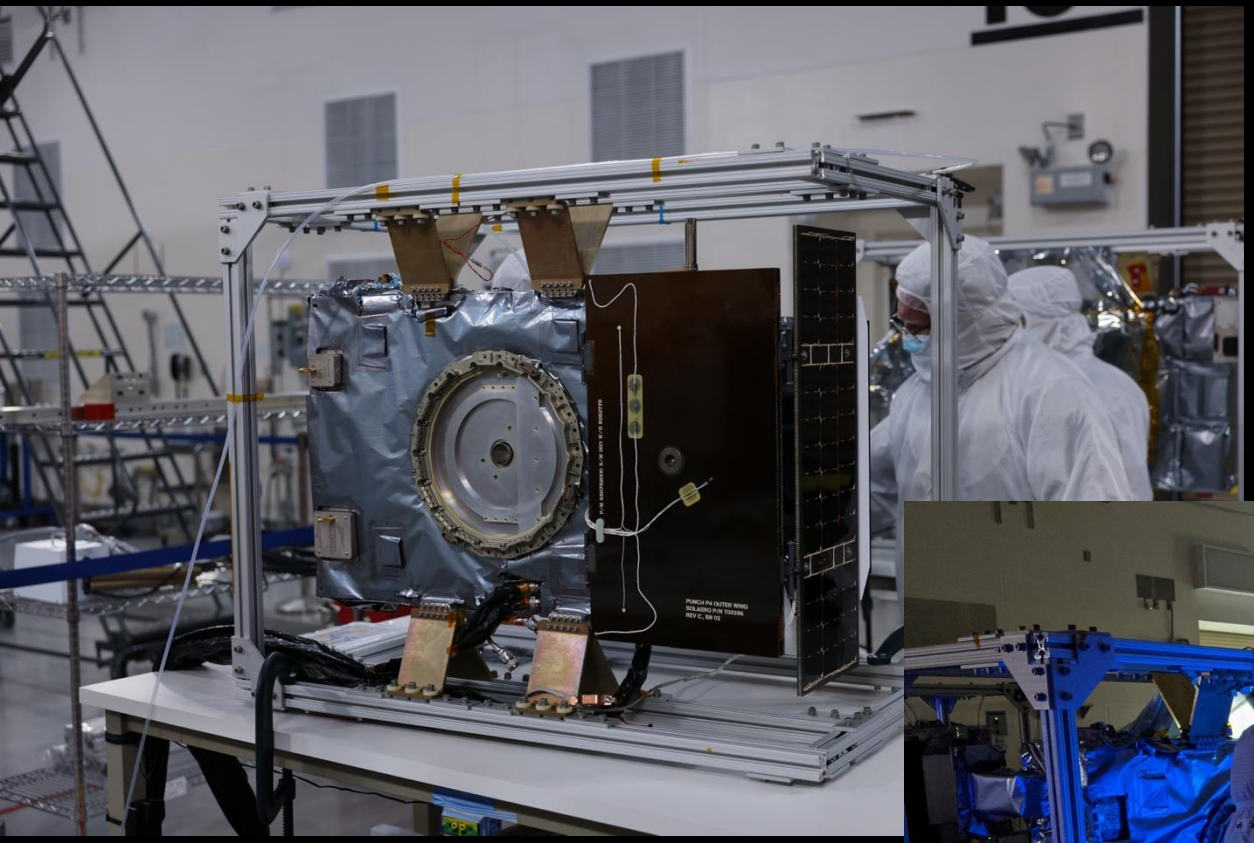

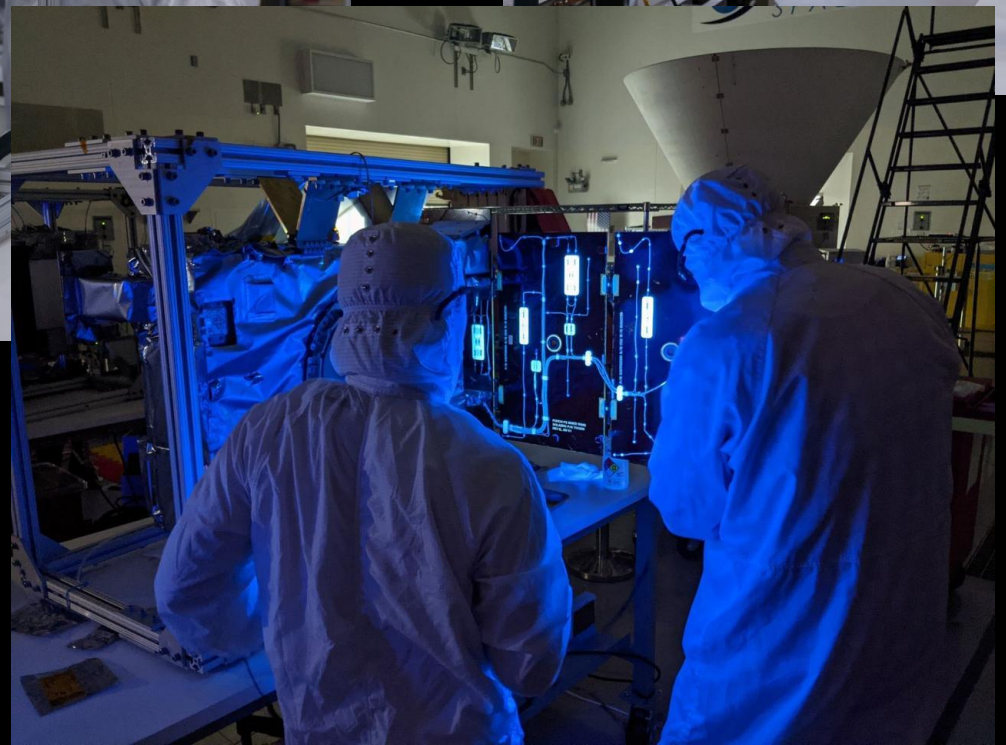

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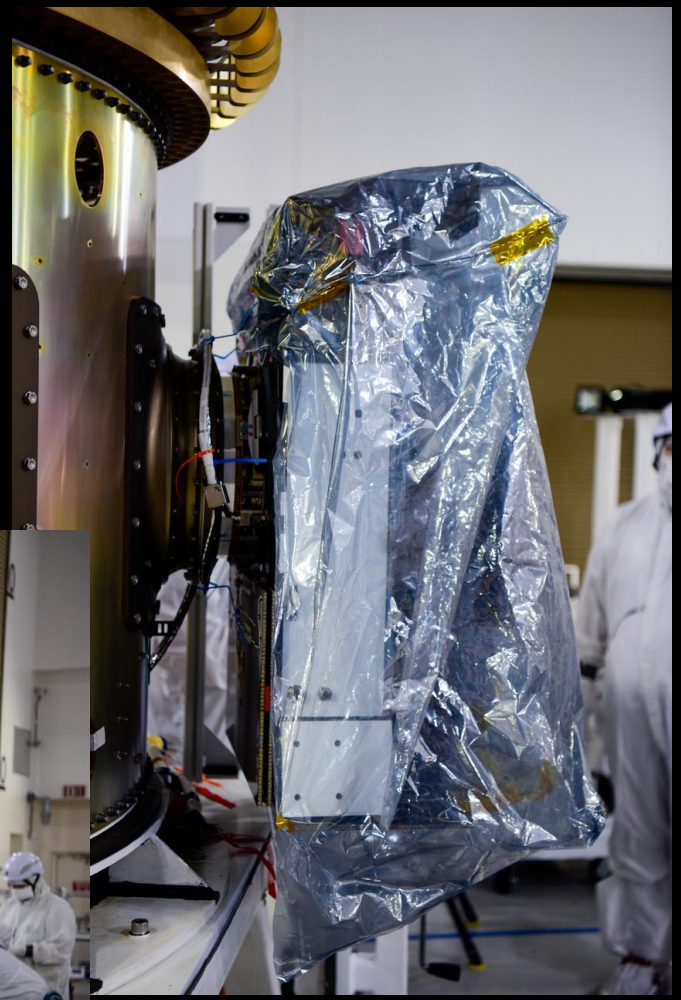
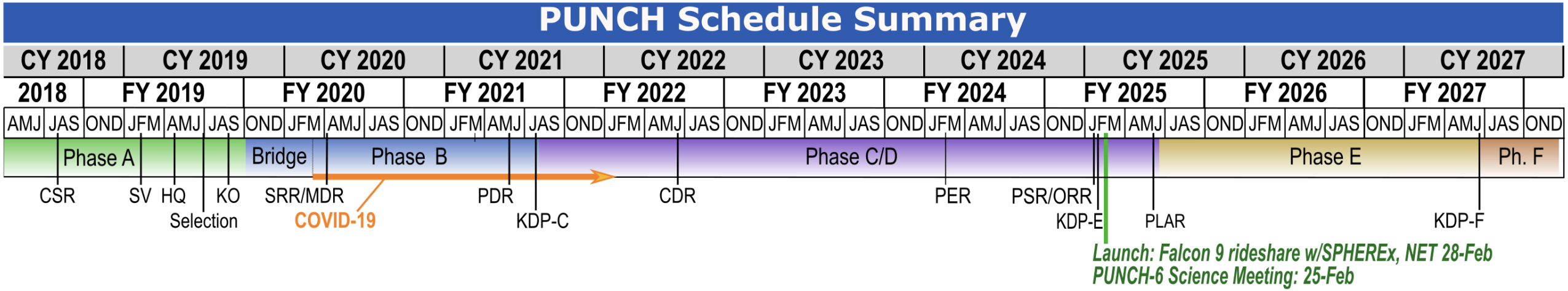


A LONG AND WINDING ROAD



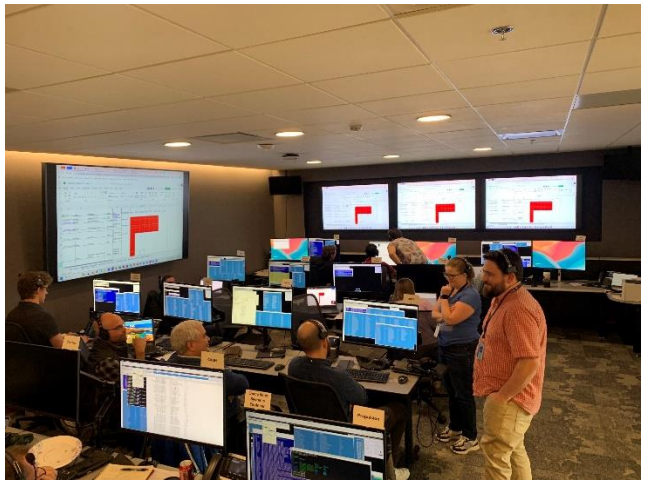
Ground systems are GO!

Ground Data Network
SSC Space

Established relationship and operating processes from CYGNSS

Science Operations Center
SwRI – Boulder, CO

Decades of SOC experience such as New Horizons, Juno, Rosetta/Alice



Mission Operations Center
SwRI – Boulder, CO

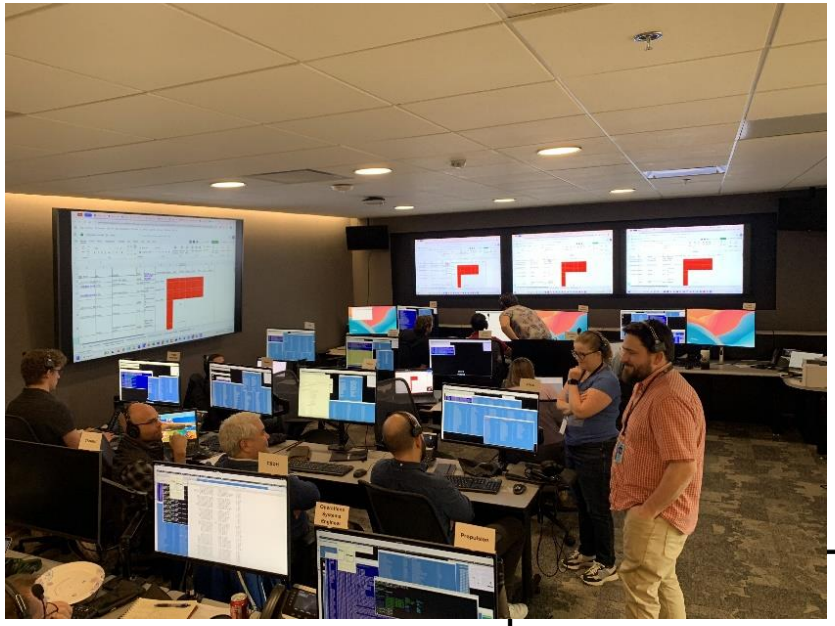
Fully operational, supporting 8-µSat CYGNSS mission with capacity for PUNCH and more

Solar Data Analysis Center

Data Archive at SDAC

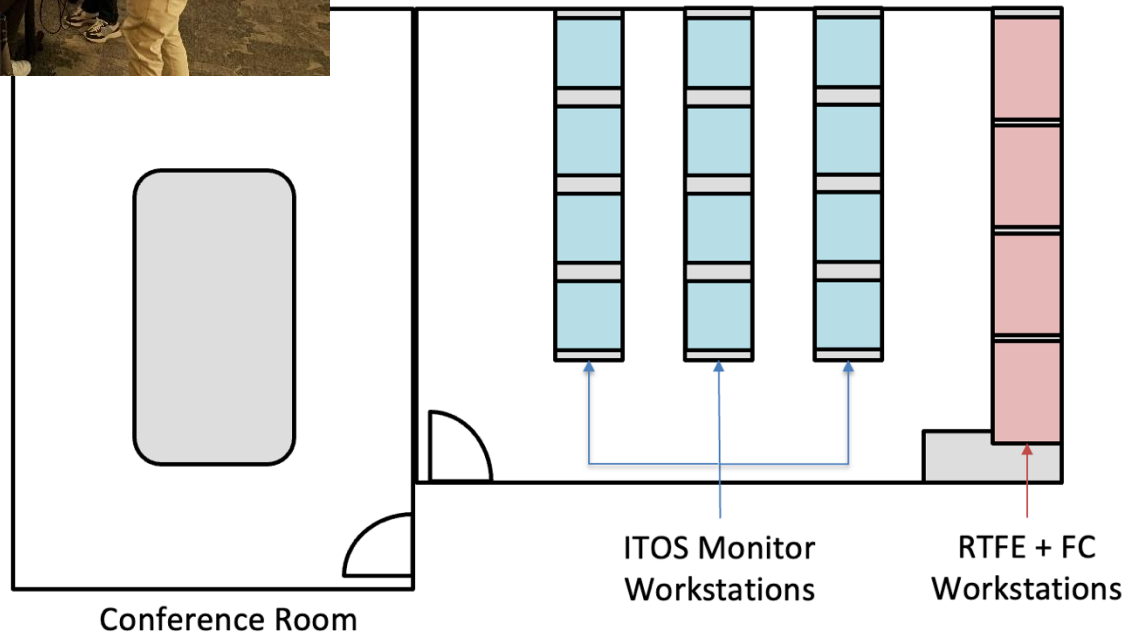
MOC Facilities are ready

- Multi-mission facility
- Located at SwRI's Boulder, CO office
- PUNCH MOC has space to support full LEOps workload
- Adjacent Conference Room: daily and ad hoc meetings; back-room technical support during LEOps
- Each Flight Controller Workstation has a computer connected to it per mission (currently CYGNSS and PUNCH)
- During PUNCH launch, CYGNSS Ops moves to the "mini-MOC"



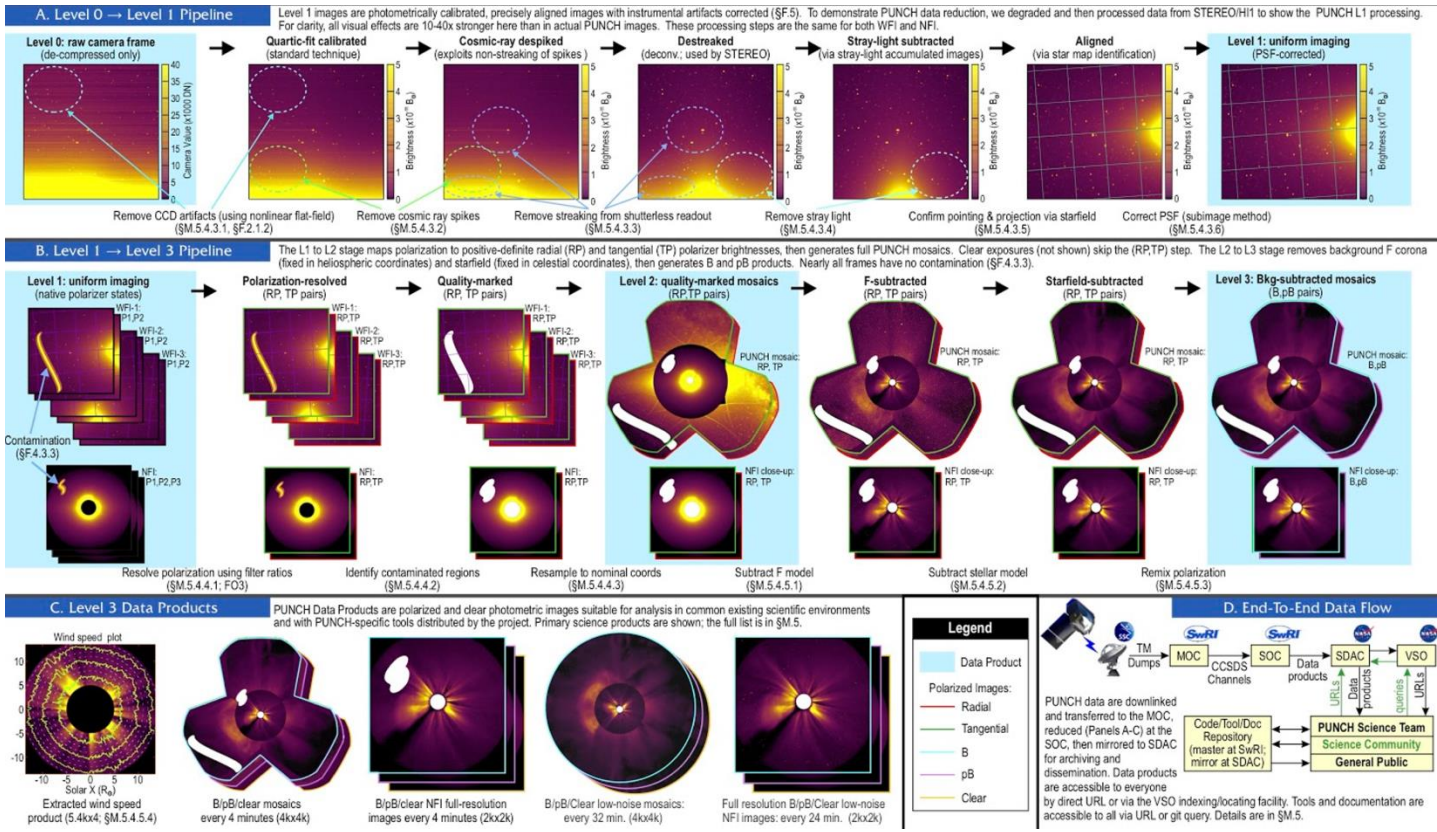
PUNCH MOC during Mission Rehearsal held Dec 10

Layout of PUNCH MOC In Boulder CO



SOC is ready

- PUNCH has the most sophisticated ground processing (SOC) of any Explorer to date.
- Advanced the state of the art in image regularization, polarization, data compression
- SOC systems are ready for launch!
- 30 days of constellation cross-calibration and pipeline checkout during 90-day commissioning campaign
- All data are made available to everyone as soon as they are made available to anyone.
- Access: via VSO and/or SDAC
- ***SOC details: this am (Hughes)***
- ***Tutorial session: this am (Lowder)!***



Overview & Status: C. DeForest

The PUNCH Science "Dream Team"

- **The PUNCH Science Team spans the nation and the globe.**
- All-star cast unites multiple fields of heliophysics.
- International contributions (not required for closure) add resilience, breadth.

Aberystwyth University

Johns Hopkins University Applied Physics Lab

Boston College

Cooperative Institute for Research in the Environmental Sciences

European Space Agency

George Mason University

High Altitude Observatory

Imperial College London

Indian Institute of Astrophysics

Institut de Recherche en Astrophysique et Planétologie

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

Naval Research Laboratory

Princeton Plasma Physics Laboratory

Rutherford Appleton Laboratories

Southwest Research Institute

University of CA, Berkeley: Space Space Sciences Lab

University of CA, SD: Center for Astrophysics & Space Science

University of Delaware

University of Sydney

International Institution

PUNCH science outreach extends science reach even more broadly:

- Science Team Meetings are **open to the full science community**
- **Associate Investigator** program recognizes and encourages talented young scientists

PUNCH Science Team is Ready

Primary working groups are organized.

Solar Wind Flow	Turbulence	Alfvén Zone	CMEs	CIRs	Shocks
WG1A	WG1B	WG1C	WG2A	WG2B	WG2C
Raphael Attié	**Nicki Viall-Kepko**	**Rohit Chhiber**	**Anna Malanushenko**	**Curt de Koning**	**Heather Elliott**
Steve Cranmer	Steve Cranmer	Robin Colaninno	Joan Burkepile	Russ Howard	Amir Caspi
Heather Elliott	Cut de Koning	Steve Cranmer	Curt de Koning	Dusan Odstrcil	Mihir Desai
Don Hassler	Heather Elliott	Dave McComas	Heather Elliott	Elena Provornikova	Glenn Laurent
Bernie Jackson	Bill Matthaeus	Nour Raouafi	Russ Howard	Dave Webb	Bill Matthaeus
Dusan Odstrcil	Arnaud Thernisien	Gilly Gilbert	Bernie Jackson	*Doug Biesecker*	Dusan Odstrcil
Nour Raouafi	Rohit Chhiber	*Jackie Davies*	Barbara Thompson	*Mario Bisi*	Barbara Thompson
Barbara Thompson	Francesco Pecora		Elena Provornikova	*Volker Bothmer*	Nicki Viall-Kepko
Rohit Chhiber	Yan Yang		Dave Webb	*Vic Pizzo*	*Volker Bothmer*
Samaiyah Farid	*Dipankar Banerjee*		*Doug Biesecker*	*Huw Morgan*	*Iver Cairns*
Bea Gallardo-Lacourt	*Mario Bisi*		*Mario Bisi*	*Divya Oberoi*	*Jackie Davies*
Doug Biesecker	*Richard Harrison*		*Volker Bothmer*		*Huw Morgan*
Mario Bisi	*Divya Oberoi*		*Jackie Davies*		*Divya Oberoi*
Huw Morgan			*Alexis Rouillard*		*Vic Pizzo*
					Alexis Rouillard

Working Group Lead: Bold
PUNCH Assoc. Investigator: green
Domestic contribution: blue
Foreign contribution: orange

Topical focus groups have completed their preparations:

Flow tracking: method selected; algorithm transferred to SOC

CME Challenge: 3D location validated with forward models

PUNCH AIs: science powerhouse

- PUNCH AI program: recognizes and encourages talented young scientists (“team on-ramp”)
- 9 AIs have been nominated and accepted across all WGs
- AI activity has been instrumental
- Active AIs are being funded as Co-Is in Phase E.

Raphael Attié
George Mason University and NASA GSFC
PUNCH Associate Investigator: WG 1A (co-lead)
more

Luke Barnard
University of Reading, Reading, UK
PUNCH Associate Investigator: WG 2B
more

Rohit Chhiber
University of Delaware and NASA GSFC
PUNCH Associate Investigator: WG 1A, 1B, 1C (co-lead)
more

Samaiyah Farid
NCAR: High Altitude Observatory
PUNCH Associate Investigator: WG 2A
more

Bea Gallardo-Lacourt
USRA & NASA/GSFC
PUNCH Associate Investigator: WG 1A
more

Chris Gilly
Laboratory for Atmospheric and Space Physics
PUNCH Associate Investigator: WG 1C
more

Francesco Pecora
University of Delaware
PUNCH Associate Investigator: WG 1B
more

Elena Provornikova
Johns Hopkins University Applied Physics Laboratory
PUNCH Associate Investigator: WG 2A, 2B
more

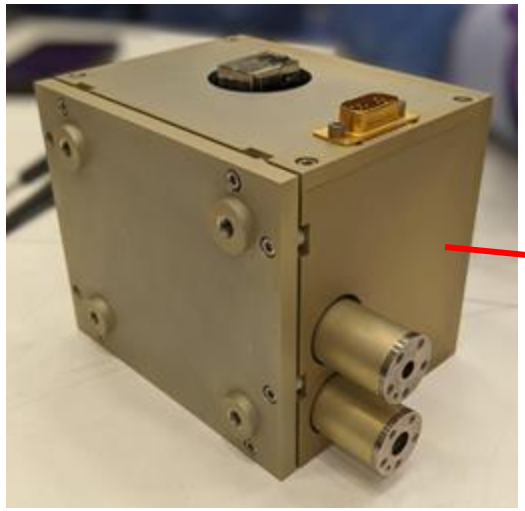
Yan Yang
University of Delaware
PUNCH Associate Investigator: WG 1B
more

STEAM project

- STEAM is a successful educational/training project.
- Students designed, built, and tested an X-ray spectrometer
- Over 50 students have interacted with STEAM!

STEAM
Student Thermal Energetic Activity Module
PUNCH

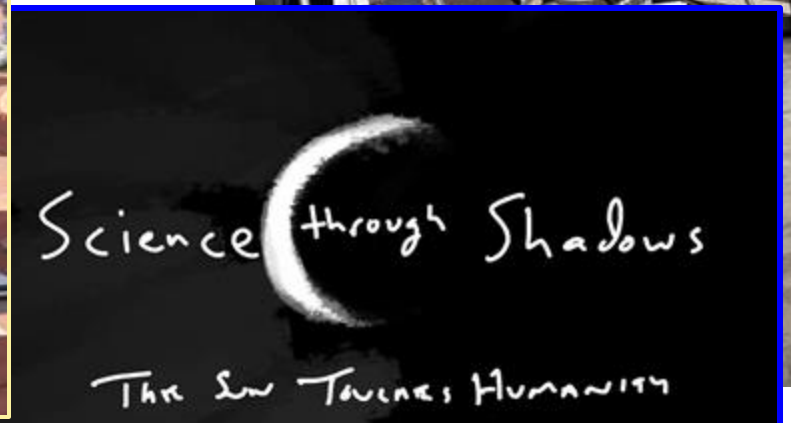
- Notable highlights:
  - Design process & parts selection
  - EM -> FM integration process
  - Project management training
  - Presentation training
  - I&T program



- Notable difficulties:
  - One channel failed during vibe (response was exemplary)
  - Self test failed during TVAC; instrument stuck in safe mode (and now powered down)
  - STEAM will remain powered down throughout the primary mission.

PUNCH Outreach: Lighting up Kids (and adults) Everywhere

- Built around “ancient and modern sunwatching”
- Building the next generation of heliophysicists & scientists
- Novel pedagogy and aids to improve STEM engagement
- Tested, vetted, and optimized methods
- Has directly affected over 250,000 children
- **Regional design, national impact**



IT'S TIME TO CHANGE THE WORLD!