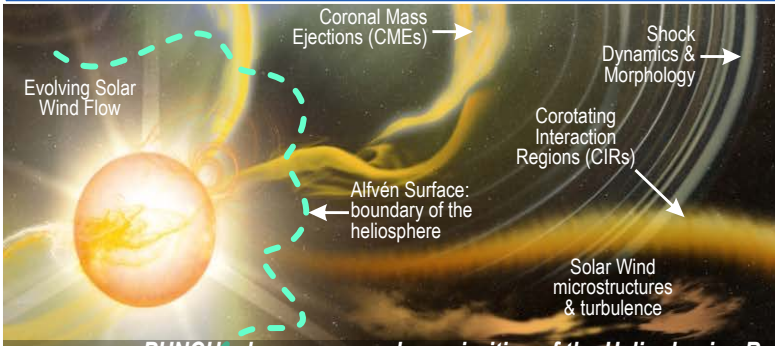
PUNCH — Polarimeter to Unify the Corona and Heliosphere

Science Goal: To determine the cross-scale processes that unify the solar corona and heliosphere

Science Objectives



1. Understand how coronal structures become the ambient solar wind.
- Map evolving solar wind flow
- Identify microstructure and turbulence
- Locate the Alfvén surface

2. Understand the dynamic evolution of transient structures in the young solar wind.
- Track CMEs and their evolution in 3D
- Measure CIR formation & evolution
- Determine large-scale shock dynamics

PUNCH advances many key priorities of the Heliophysics Roadmap and Solar & Space Physics Decadal Survey.

Mission Overview

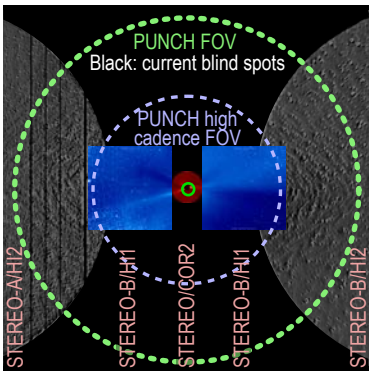
PUNCH makes global, deep-field, 3D observations of the young solar wind from the solar corona to the inner heliosphere, closing a 50-year gap in measurement and understanding.

A constellation of 4 small satellites in Sun-synchronous LEO produces deep field, continuous, 3D images of the corona and young solar wind from $6R_\odot$ to $180R_\odot$ in polarized visible light. Each spacecraft carries one instrument. A Narrow Field Imager (NFI) captures the entire outer corona from $6R_\odot$ to $32R_\odot$. Three Wide Field Imagers (WFIs) capture from $20R_\odot$ to $180R_\odot$.

- **Visible-light Thomson imaging from LEO**
- Deep-field (polarized) global 3-D imaging
- 2-year science mission: 2022-2024
- Bridges & unifies solar, heliospheric physics
- Relevant to National Sp. Wx. Strategy
- Complements SPP & SO missions

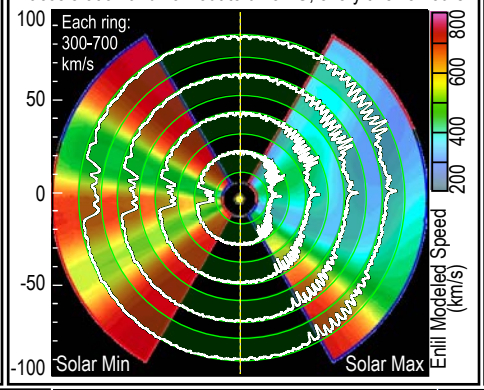
Global images of the young solar wind

PUNCH delivers the first complete, photometric, high resolution views of the corona/solar wind transition.



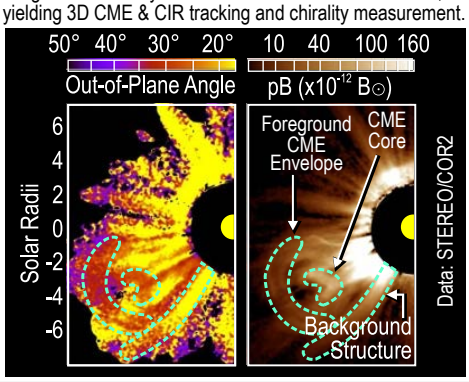
Frequent mapping of solar wind flow

PUNCH uses image motion analysis to map solar wind acceleration and flow out to 0.25 AU, every twelve hours.



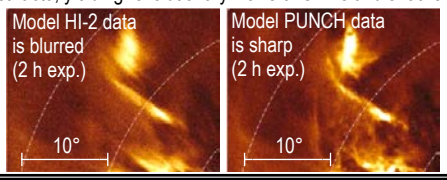
Polarization for precise 3D imaging

PUNCH creates the first wide-field polarimetric solar wind images. Photometry is >10x better than STEREO/COR2, yielding 3D CME & CIR tracking and chirality measurement.



Blur-Free CME and shock imaging

PUNCH downlinks data at high cadence. Images are deblurred post-facto, yielding revolutionary views of CMEs and shocks.

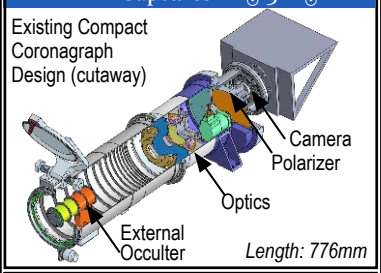


Key Instrument Characteristics

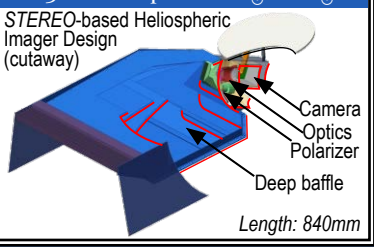
	NFI			WFI		
Resources	CBE	Cont.	Tot.	CBE	Cont.	Tot.
Length (mm)	776	-	776	840	-	840
Mass (kg)	8.9	18%	10.5	10.6	18%	12.5
Power (W)	21	15%	24.2	21	15%	24.2
Data (Mb/s)	0.21	15%	0.24	0.15	15%	0.17
Requirements	Req't	Cap'y	Mgn	Req't	Cap'y	Mgn
Resolution	2'	1'	2×	4'	3'	33%
Sensit'y ($B_\odot$)	10^{-14}	6×10^{-16}	17×	5×10^{-16}	7×10^{-17}	6×
Cadence	Matched/Synchronized: 4 min. (Req. 8 min)					
W/L Range	Matched: 400-700 nm (common filter)					

Instrument Complement

NFI Captures $6R_\odot$-$32R_\odot$

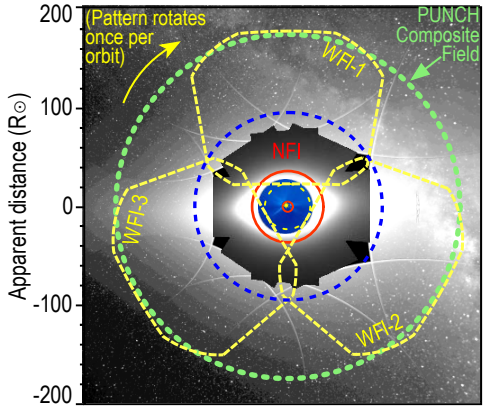


3 WFIs Capture $20R_\odot$-$180R_\odot$



Observing Strategy

- PUNCH observes continuously at 4-min. cadence.
- NFI covers $6R_\odot$-$32R_\odot$ (Red circles: inner/outer).
- WFI covers $20R_\odot$-$180R_\odot$ in 3 parts (Yellow dash trefoil).
- PUNCH images continuously inside 80 $R_\odot$ (Blue dots).
- PUNCH produces 3 full mosaics per orbit, outside 80 $R_\odot$.



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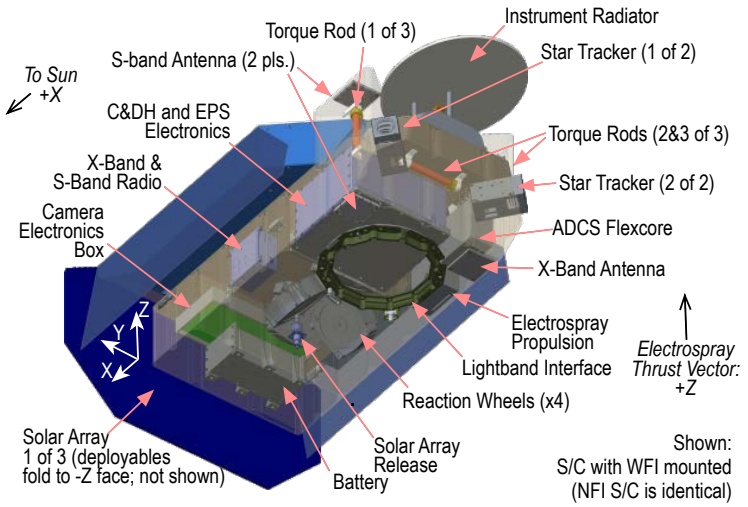
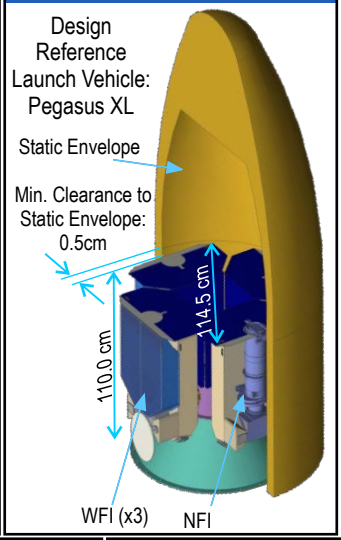
PUNCH Spacecraft & Observatory



PUNCH fits NASA LVs

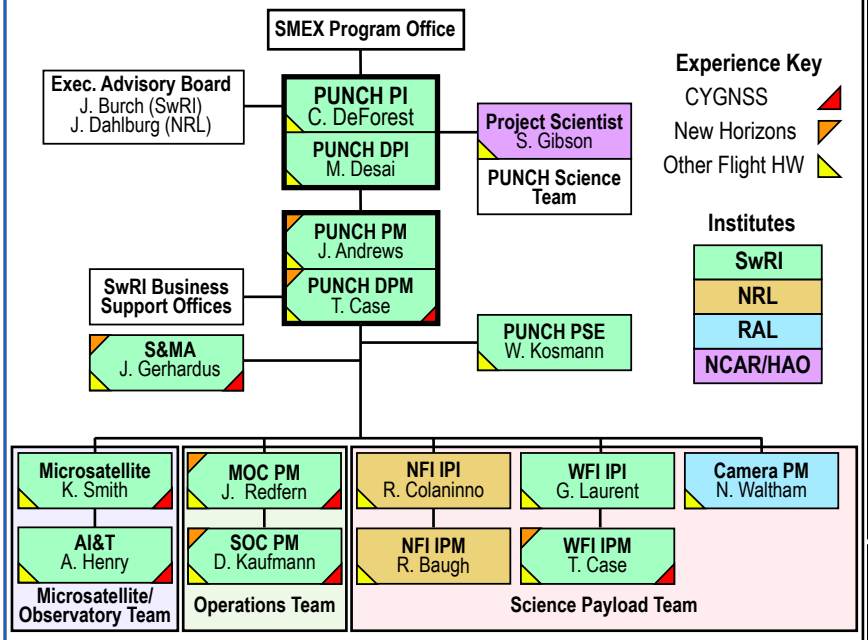
Design Reference Launch Vehicle: Pegasus XL



PUNCH Mission Profile

- Launch Readiness: July 2022
- LV: Design ref. is Pegasus XL
- Launch mass (CBE+C): 199kg (25% margin to Pegasus cap.)
- Orbit: Sun-synch LEO 6am/6pm
- Target altitude: 550 km
- 4 Observatories deploy from LV
- WFIs drift 120° apart (90 days)
- Electric propulsion stops drift.
- Phase E duration: 2 years
- Passive re-entry: 13 years
- Ground contacts: NASA/NEN
- D/L: X-band 25 Mbps (16PSK)
- MOC & SOC: SwRI
- Critical Events (2): Deployment from LV; S/A deploy

PUNCH Team Structure



Key Spacecraft Characteristics

Mass (CBE+C):	NFI Observatory (x1): 41.8 kg WFI Observatory (x3): 43.8 kg Separation Module: 26.7 kg	
Power (CBE+C):	Science Mode (orb. avg): 63W Safe Mode (SA deployed): 42W Early Ops (Pre-SA deploy): 38W	**S/A cap.:** 130W EO: 78W
Data Volume:	NFI: 18.8 Gb/day WFI(x3): 13.4 Gb/day **Total**: 59.0 Gb/day	NEN passes: 25 Mbps D/L
ADCS: 3-axis, Sun-pointed	Stability (jit+dr, 45 s): Req. 9.6" Cap. 7.2" Mgn. 34% Accuracy: 80" 30" 2.7x Authority: 3x above env. & thrust torques	
Propulsion:	Type: low-thrust inert electrospray Δv: req.1.5 m/s cap. 2.4 m/s Used for: 1 phasing burn, L+90d, dur. 10d	
Deployments:	LV Separation (Motorized Lightband) Solar Panel Deploy (1-time release) Inst. Door Deploy (1-time release)	

PUNCH Major Participating Organizations

Organization	Role
Southwest Research Institute	Lead, WFI, S/C, Sep. Module, MOC, SOC
Naval Research Laboratory	NFI; Science
Rutherford Appleton Laboratory	Cameras; in-flight cal.

PUNCH Cost Summary (2017 $k)

PUNCH Total Cost (A-F), no reserves	$141,289
Reserves (29.3% for B/C/D excl. LV; 10% for E/F)	$23,700
PI-Managed Mission Cost	**$164,989**
Contributions (science Co-Is, foreign & domestic)	$ 2,618
Total Mission Cost	**$167,607**
SEO (GIs: Sp. Wx application; SPP/SO/PUNCH synergy)	$ 6,605
Enhanced PI-Managed Mission Cost	**$171,594**

- *Costs include support for all AO-deferred items.*
- *$50M for NASA LV carried in C/D with no reserves (per AO)*

By phase:	A: $1,250	B: $24,163	C/D $124,271	E: $13,929	F: $1,376

PUNCH Schedule