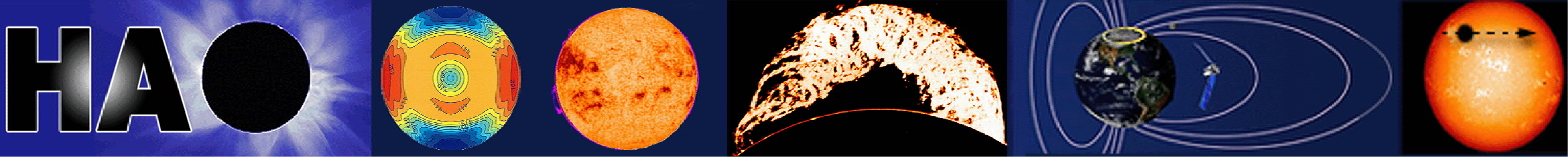

Spectro-Polarimeter for Infrared and Optical Regions (SPINOR) Conceptual Design

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HAO SPINOR Team

- Hector Socas-Navarro PI
- Steve Tomczyk Co-PI
- David Elmore Lead Engineer
- Kim Streander Project Manager

SPINOR is

- Next generation HAO/NSO Research Spectro-polarimeter for the Dunn Solar Telescope (DST) extending the capabilities of the Advanced Stokes Polarimeter (ASP) through the next decade
- Modular: seamless transition from the ASP to SPINOR
  - SPINOR optics work for ASP
  - SPINOR computers and cameras are entirely new allowing for simultaneous availability during the transition
  - Control integrated into overall DST control network
- Reliable
  - New maintainable hardware
  - Robust networking
- Demonstrator of ATST concepts
  - Achromatic polarization optics
  - High frame rate large format thinned CCDs

And SPINOR is better

- Improved performance compared to ASP
  - Wavelength coverage extends to infrared
  - Higher signal to noise at visible wavelengths
  - Better spatial resolution
  - Larger field of view
  - Larger spectrum length
  - More versatile due to integration into overall DST software control system

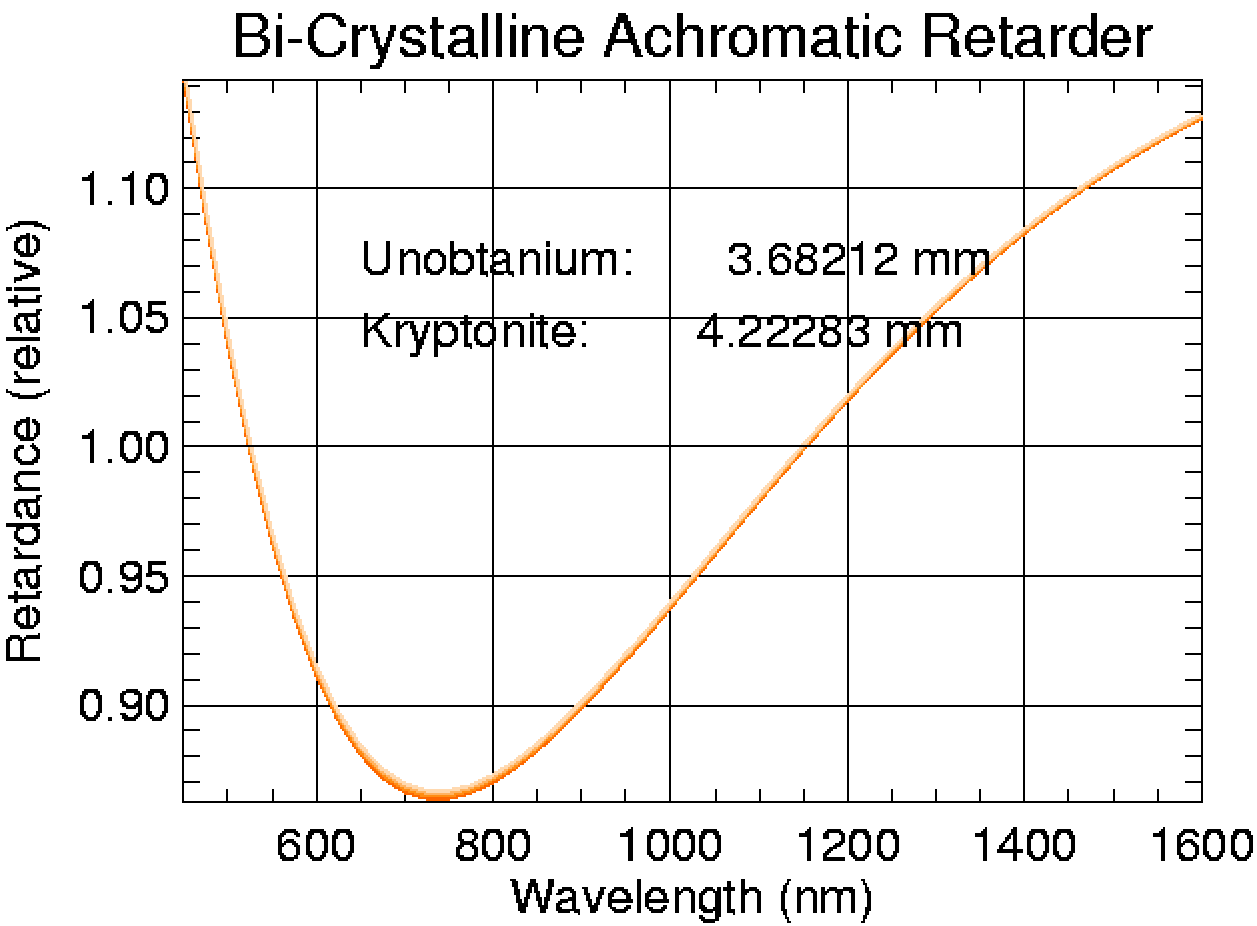
SPINOR Optics

- Retain ASP optical mechanisms
- Replace polarization optical elements with achromatic ones
  - Entrance window polarizer
    - Array of Versalight linear polarizers
  - Calibration linear polarizer
    - AR coated Versalight linear polarizer
  - Calibration retarder
    - Bicrystalline achromatic retarder
  - Polarizing beam splitter
    - Versalight beam splitter cube
- Spectrograph camera lenses optimized for SPINOR cameras

Design retardance vs. wavelength of bicrystalline achromatic retarder. Thicknesses shown are for 1 wave mean retardance.

Colored curves are for temperatures of 10C to 40C

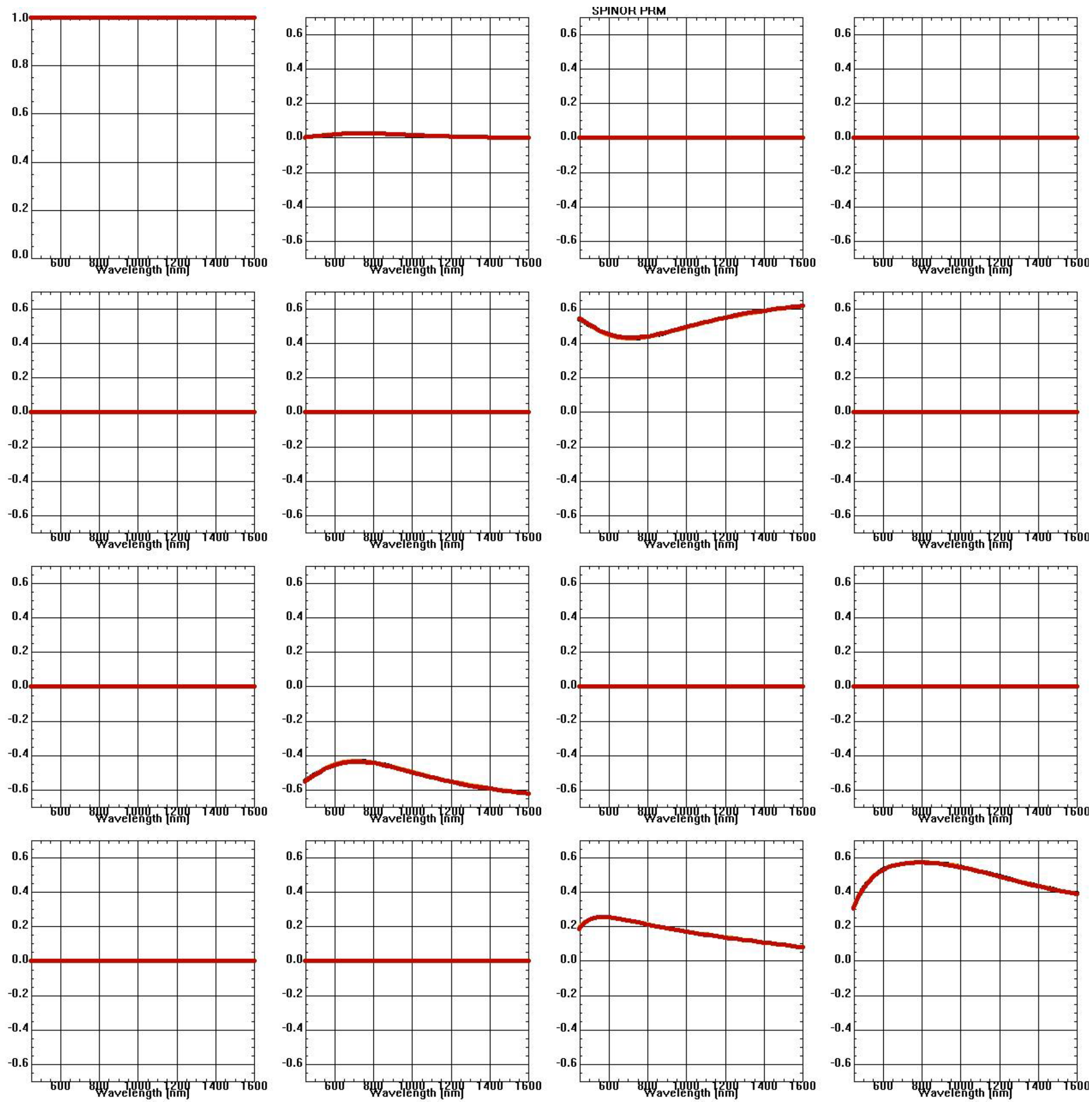
Proprietary design by Meadowlark Optics includes positive and negative birefringent crystals



Polarimeter response matrix (PRM) including a net of two 45° aluminum reflections between modulator and spectrograph.

PRM is for a merged dual beam polarimeter, therefore Q>I crosstalk is small.

Off diagonal 2,3 and 3,2 elements can be moved to 2,2 and 3,2 through phasing of the polarimeter, but that same phasing moves 4,4 to 4,3. The ‘fix’ is a half wave retarder at 22.5° in front of the PBS, but the cost for an additional achromatic retarder is high.



SPINOR, ASP, & Solar-B @ 630nm

Specifications at 630nm	SPINOR 1280 X 1024	ASP 230 X 512	Solar-B 1024 X 224	Units
Spatial Sample	0.27	0.375	0.159	Arc-sec.
Spatial Slit Height	160	86	163	Arc-sec.
Spectral Sample	1.86	1.08	2.02	pm
Spectral Resolution[1]	2.77	2.93	3.13	pm
Spectral Range (max)	1.90	0.55	0.45	nm
Spectral Range (typ.)	0.37	0.28	0.23	nm
Wavelength Min.	450	420	630	nm
Wavelength Max. (Si)	900	750	630	nm
Wavelength Max. (HgCdTe)	1600	-	-	nm
Max. Frame Rate	15 - 120[2]	60	10	Hz

[1] Calculated RSS of slit, pixel, and grating resolution, actual performance is normally better

[2] IR 15Hz. Visible 30Hz @ max spectral range, up to 120Hz for typical spectral range

Wavelength Accessibility

Instrument and grating	517 nm	589 nm	630 nm	700nm or 656nm	855nm or 850nm	1083nm	1565nm
ASP 316 lines/mm	0.38	0.00	1.00	0.87	0.00	0.06	0.00
SPINOR 316 lines/mm	1.45	0.00	2.32	2.24	0.00	1.17	0.00
SPINOR 306 lines/mm	0.00	1.01	0.00	1.36 (656)	1.31	0.00	0.00
SPINOR 31.6 lines/mm	0.90	0.24	2.18	2.11	1.12 (850)	0.12	1.84

Signal relative to ASP @ 630nm. Included are spatial and spectral pixel sample size, grating efficiency, and detector quantum efficiency (HgCdTe for SPINOR 1000+nm). Zero indicates wavelength is not accessible. Not included are variation in solar flux vs. wavelength and variation in modulation efficiency vs. wavelength. Take square root of values for signal to noise relative to ASP @ 630nm.

SPINOR Computer Philosophy

- ‘Standards based’ software
  - TCP/IP
  - C/C++
- Open source used wherever possible
  - Linux
- Computer interfaces as close to “industry standard” as possible
  - National I/O boards
- Reuse software from HAO and NSO projects

SPINOR Computers

- NSO SPINOR instrument control computer
  - Top level control of SPINOR within DST environment
  - Access to all DST instruments
  - Java user interface
- New Polarimeter Control Computer
  - Synchronizes DST (including SPINOR) cameras to rotating retarder
  - Controls rotation rate of rotating retarder
  - Controls existing ASP Mechanism Control Computer
- New 'Virtual Camera' Computers
  - Available to any DST experiment
  - Data storage on SAN
  - Quick look display on table
  - Quality assurance display on 'Bridge'

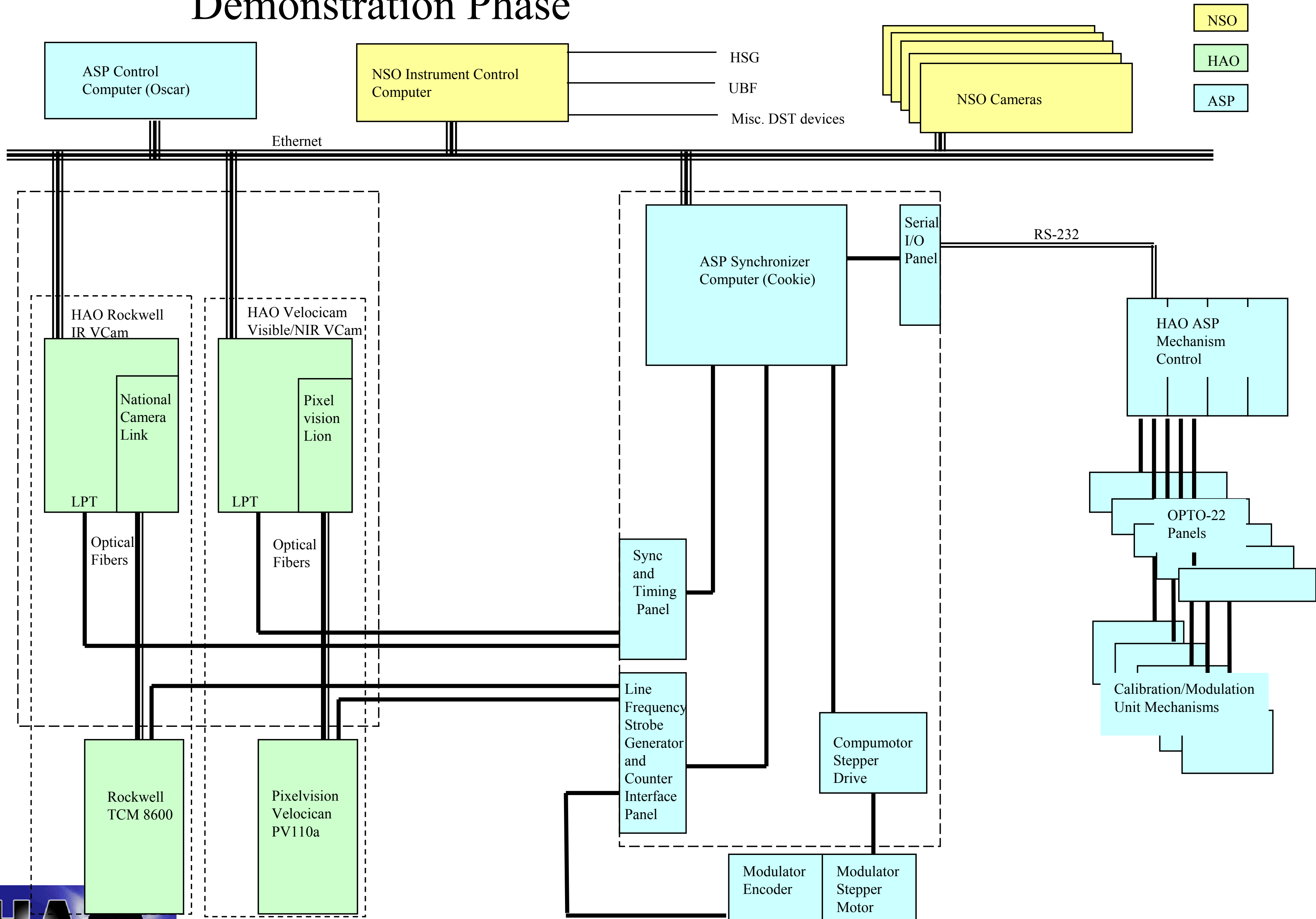
NSO Guidelines

- Keep the system neat
  - Rack mount everything, even computers
- Store data on the Storage Area Network (SAN)
- Store data in FITS format
- Ship only low bandwidth quality assurance data over the DST Ethernet

Demonstration Phase

- Demonstrate capabilities of achromatic optics
- Demonstrate operation of new camera(s)
- Use existing ASP Control (oscar) and Synchronizer (cookie) computers
- Camera TCP/IP interface software borrowed from ASP Demodulator Computers (bert and ernie)
- Camera synchronization and timing use existing ASP signals

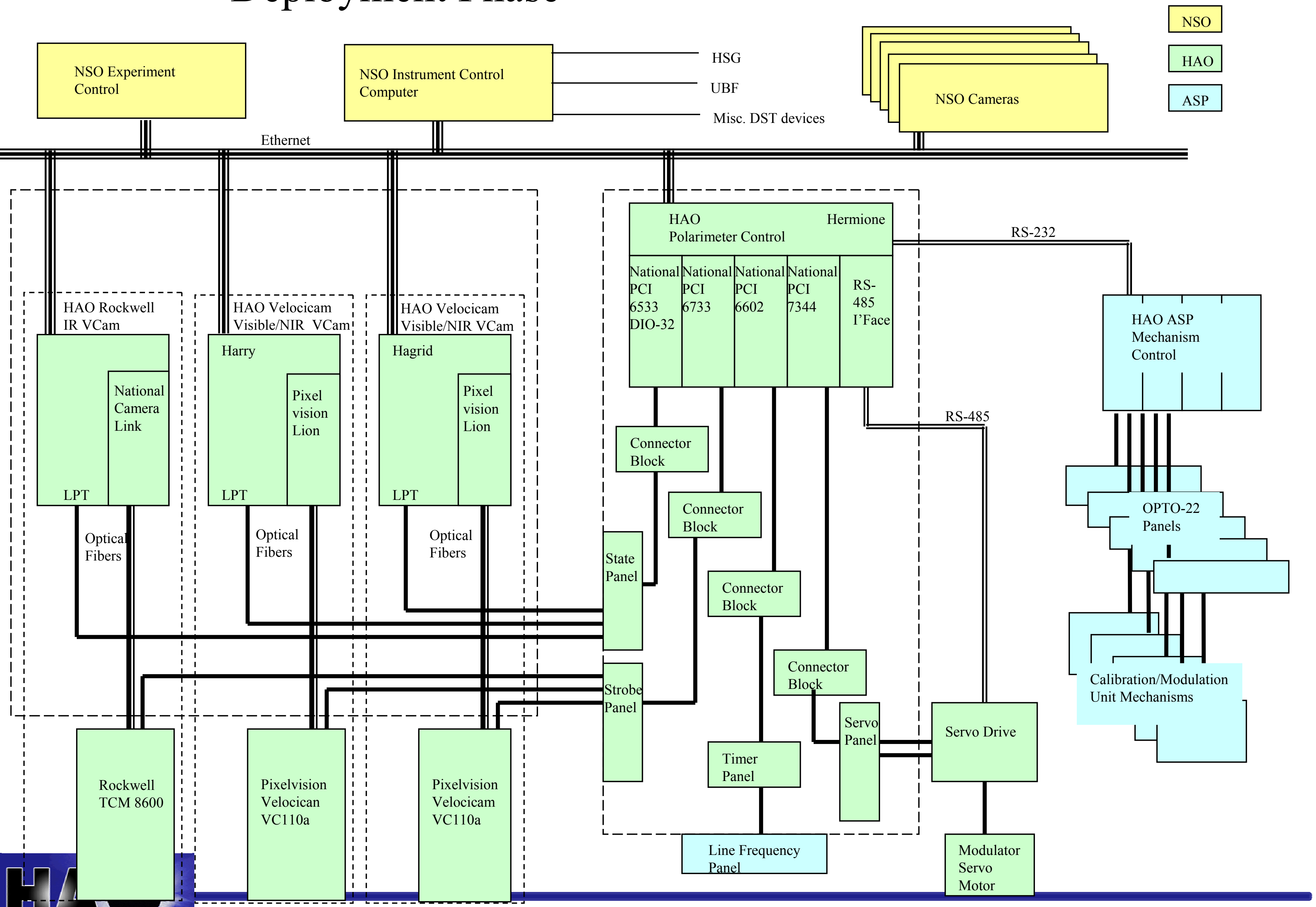
Demonstration Phase



Deployment Phase

- Polarimeter Control Computer (Hermione) implemented
  - Controls synchronization of modulator and cameras
  - Controls existing ASP mechanisms
- Virtual cameras (Harry and Hagrid) use DST camera control standard
- SPINOR control from DST Java interface (Muggle?)
- Bid farewell to the three existing Datacube computers (Bert, Ernie & Cookie), Sun workstation (Oscar), and ASP cameras

Deployment Phase



Development Plan

- Now (Early CY 2004)
  - HAO: Spend available funds on achromatic optics and 1st visible camera
  - HAO: Apply to NCAR Instrumentation fund for remaining camera, computers, interfaces, and travel
  - HAO: Complete definition of Polarimeter Control system
- CY 2004
  - HAO/NSO: Define network protocol and NSO/HAO software responsibilities for its implementation
  - HAO/NSO: Define virtual camera protocol
  - HAO: Demonstrate operation of achromatic polarization optics and cameras
  - NSO: Broadband AR coat refractive optics in SPINOR light path
  - NSO: Replace aluminum coated mirrors with those of high reflectivity
- FY 2005
  - HAO: Deploy Polarimeter Control and Virtual Cameras
  - HAO/NSO: Complete SPINOR Experiment Control user interface

Connection to other projects

- Infrared camera from COMP
- Polarization optics serve as ATST demonstration
- Virtual Cameras share with SUPOS, ChroTel, and Prominence Magnetometry initiative:
  - PixelVision camera control software
  - Linux
  - TCP/IP command interface
- Networking from DST control definition