The Hubble Space Telescope
NICMOS Cooling System (NCS)

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05 June 2002
AAS Backup Material

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SM3B Scientific Improvements For HST

- **Double the electrical power for science instruments.**
  - Combination of the new Solar Arrays and Power Control Unit.
- **The Advanced Camera for Surveys (ACS).**
  - A new camera improving the (field-of-view x sensitivity) metric by 10x.
  - Replaces the ageing WFPC2 camera (and its radiation damaged CCDs).
- **The NICMOS Cooling System (NCS).**
  - Provides external cooling for the Near Infrared Camera and Multi-Object Spectrograph (NICMOS).
  - The NICMOS solid-Nitrogen coolant was used up 2 years after deployment due to a thermal short in the cryostat (expected life was > 5 years).
  - Uses a high capacity mechanical cryocooler to provide ~ 75K at the detectors.
  - Overall cooling capacity is ~ 7 Watts.
  - Power consumption less than 400 Watts.
  - Unlike all other HST systems, this is an experimental unit that is flown on a “best effort” basis.

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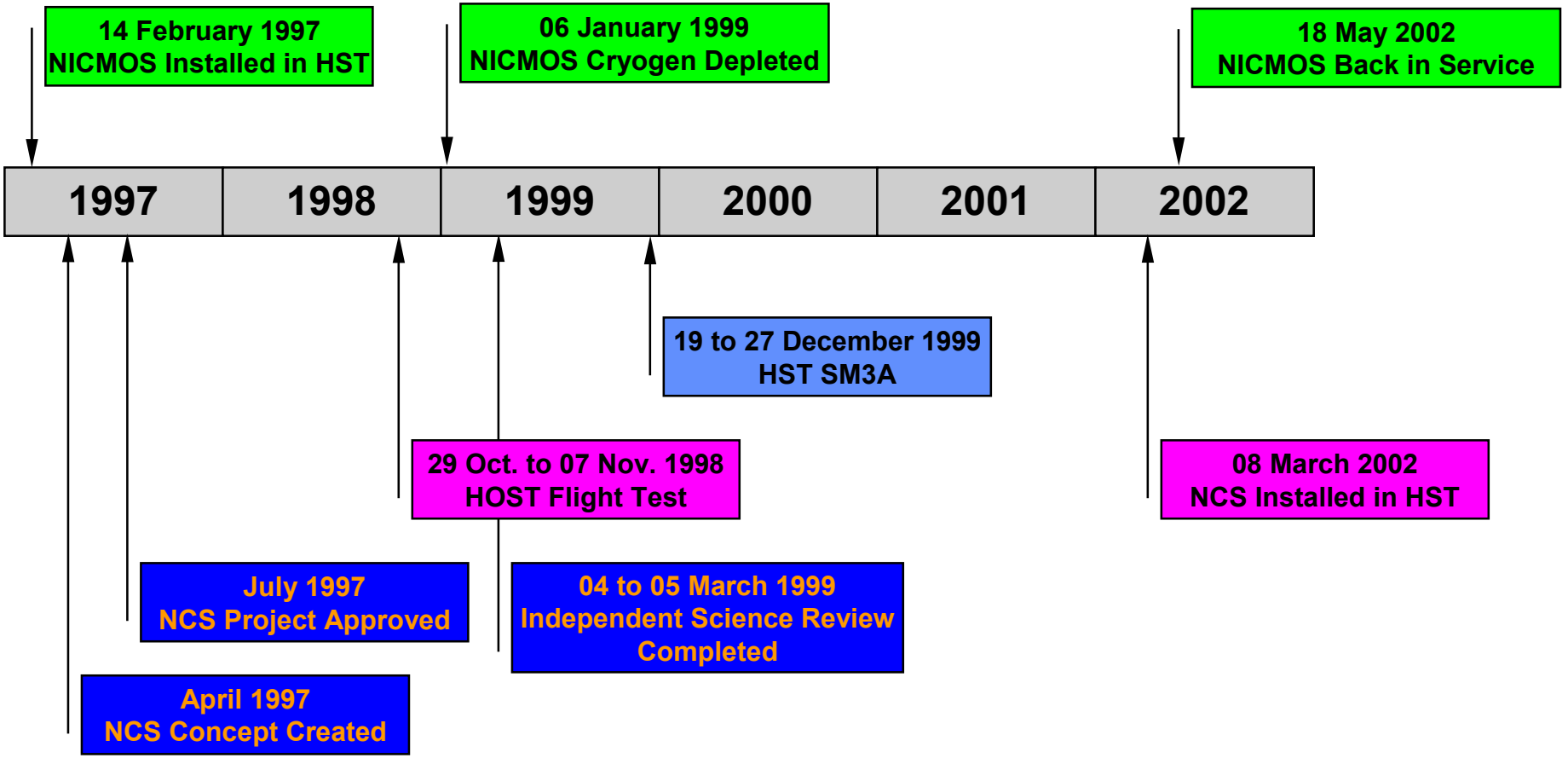
NICMOS Cooling System Development Timeline



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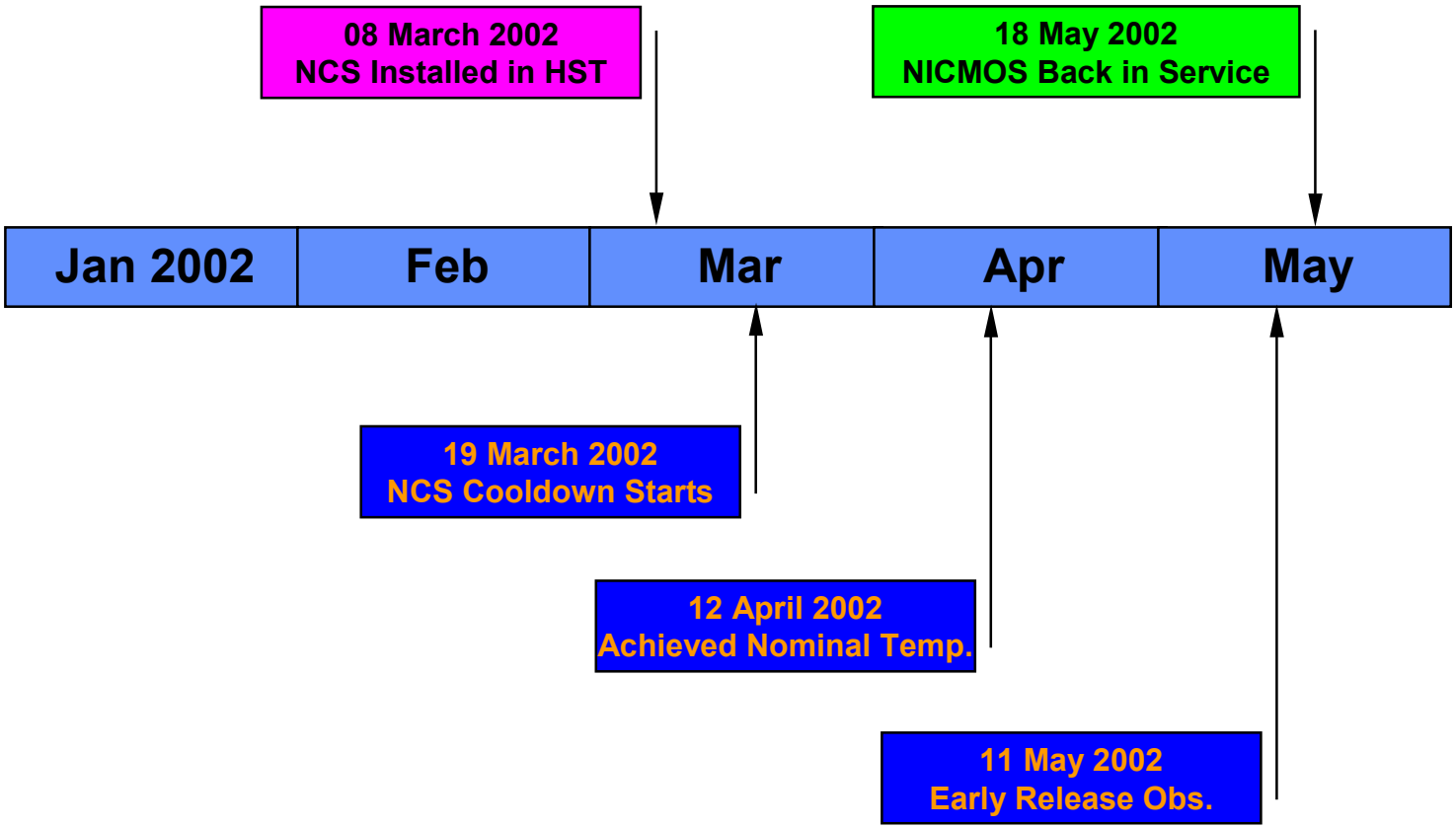
NICMOS Cooling System Deployment Timeline (2002)



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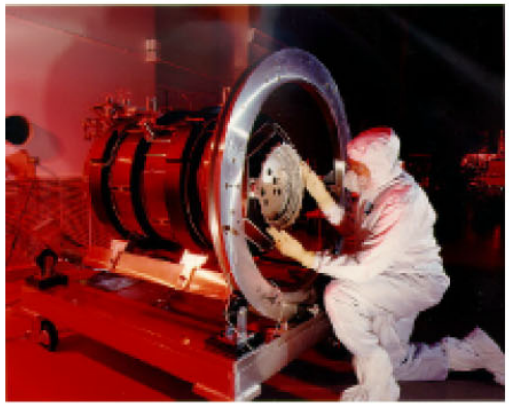
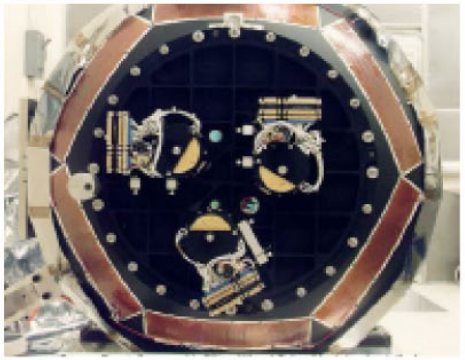
The NICMOS Instrument

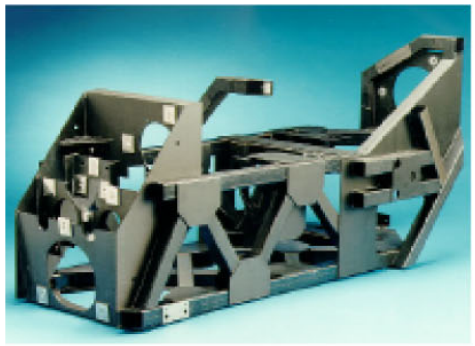
Cryostat In Assembly Fixture



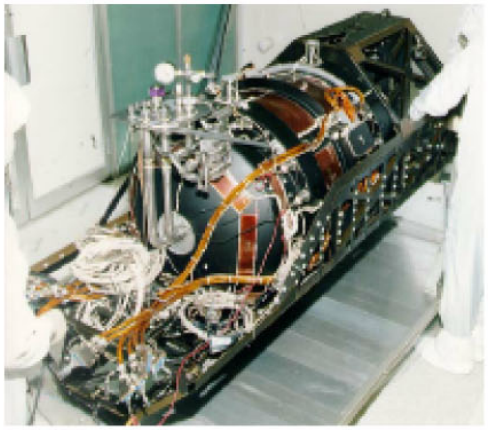
Cryostat Front View



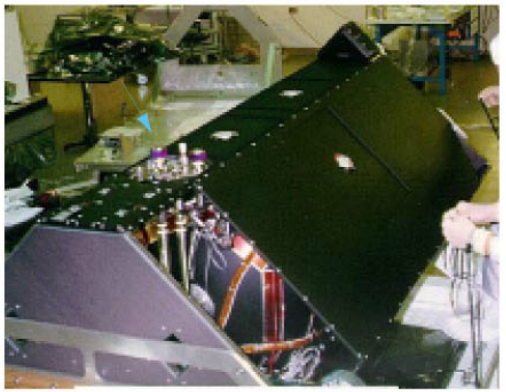
Cryostat Side View



Optical Bench



Rear View of Cryostat in the Optical Bench



The Assembled Instrument (note Cryo Interface Panel)

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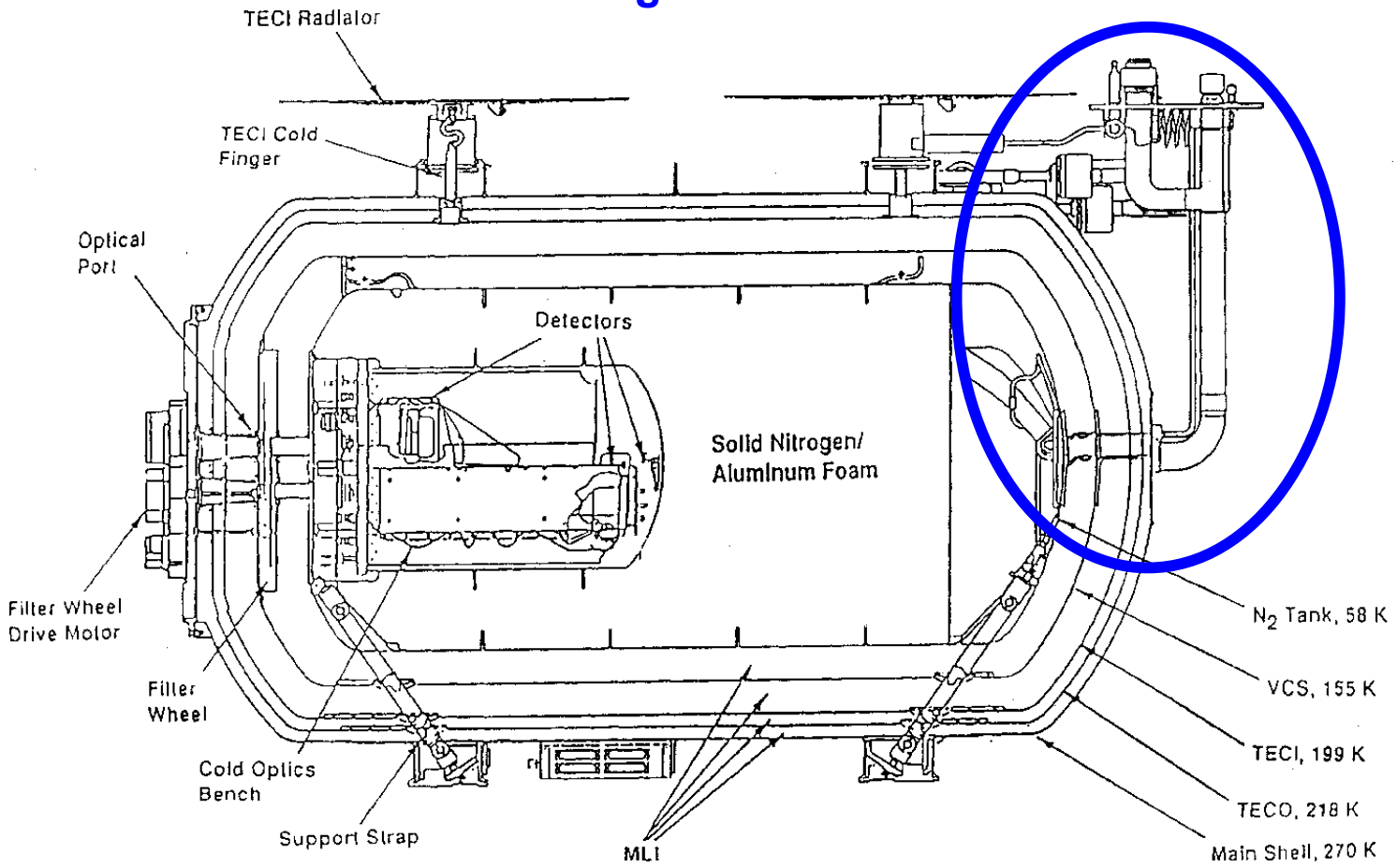
The NICMOS Cryostat

This ground servicing plumbing is used to convey the cold gas from the NCS into the instrument.



A Section Through the NICMOS Dewar's Main Shell and Nitrogen Tank

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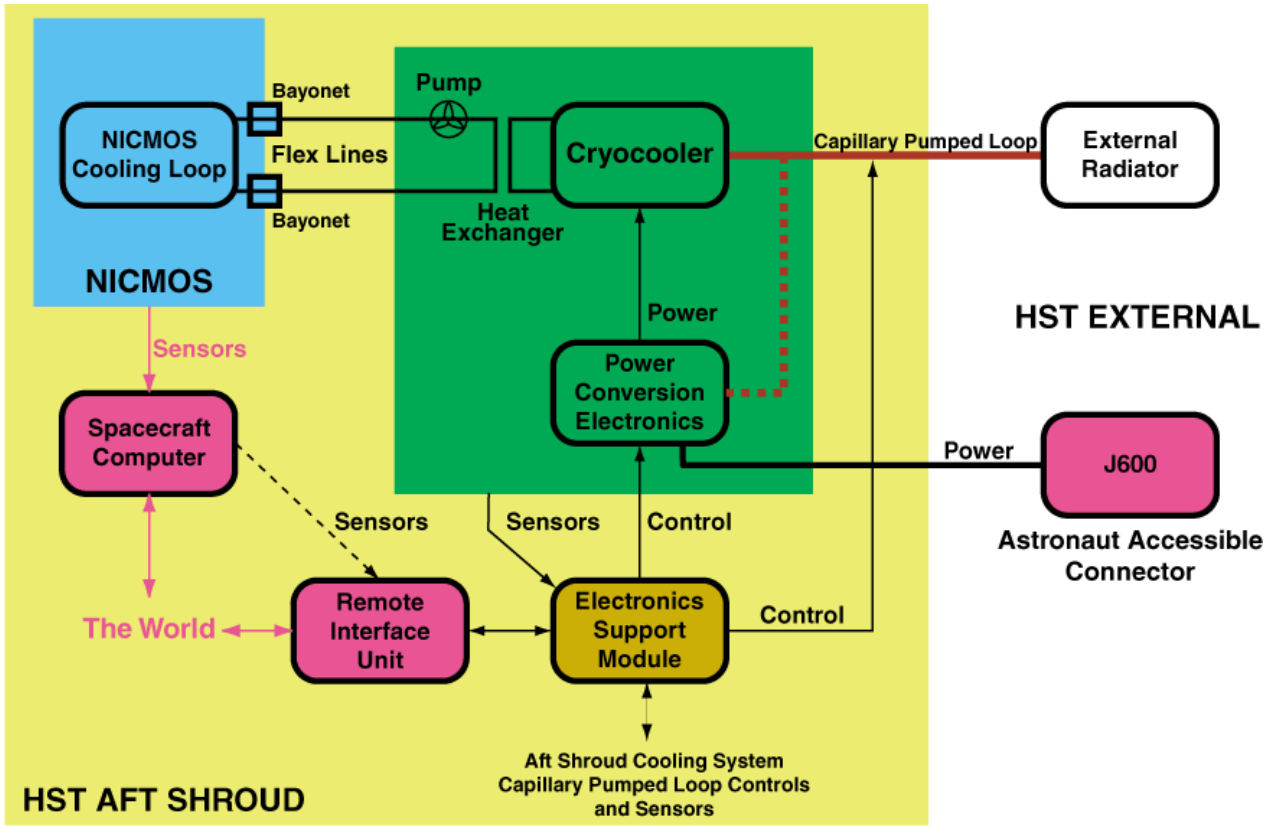
NICMOS Cooling System Block Diagram



Existing HST Spacecraft Equipment

Existing NICMOS Instrument

HST Aft Shroud

New NICMOS Cryocooler Subsystem

New Microprocessor

New Radiator and CPL

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NICMOS Cooling System Block Diagram Description

- **The NCS operates with three fluid loops.**
- **The Circulator Loop conveys cold Neon gas from the cryocooler to the NICMOS cryostat (and back).**
  - The gas is moved by a tiny turbine electrical pump (72,000 RPM).
- **The Compressor Loop internal to the cryocooler also uses Neon gas, and implements a reverse Brayton cycle refrigerator.**
  - The compressor is a tiny turbine on the hot side driven by electrical power (420,000 RPM).
  - The turboalternator is a tiny turbine on the cold side that does electrical work to generate the cooling (180,000 RPM).
- **The Capillary Pumped Loop uses anhydrous ammonia gas and liquid to convey the heat (~ 400 Watts) generated by the cryocooler to the external radiator.**
  - The CPL includes a flexible portion inside the Aft Shroud, and a rigid length running along the bottom of the HST.

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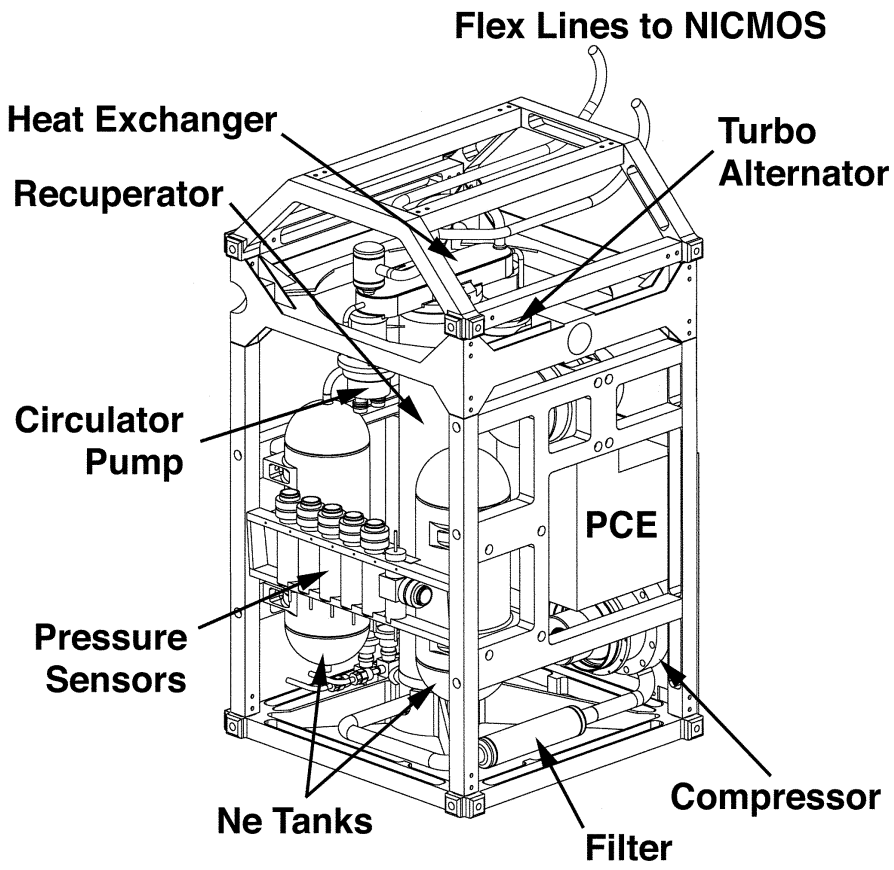
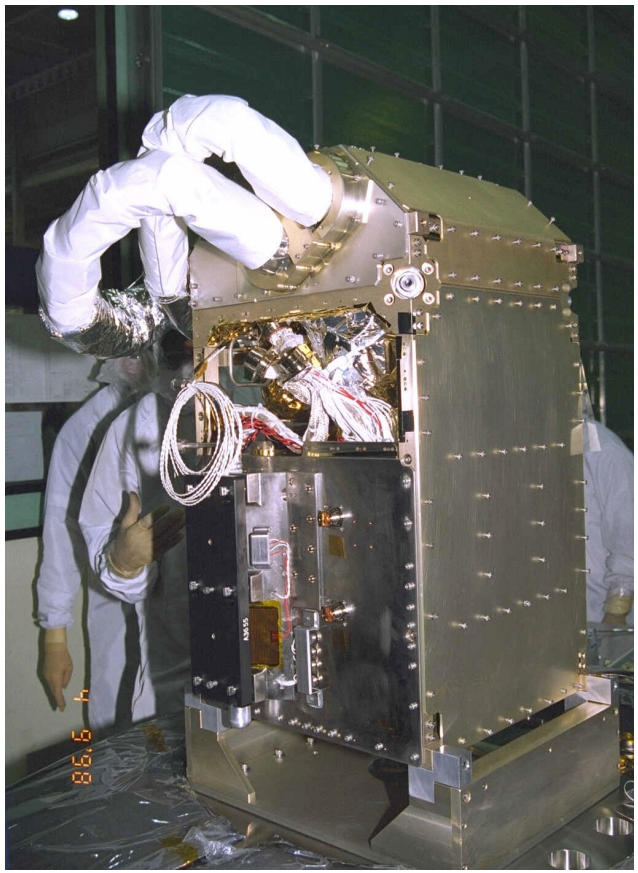
NCS Cryocooler Mechanical Layout





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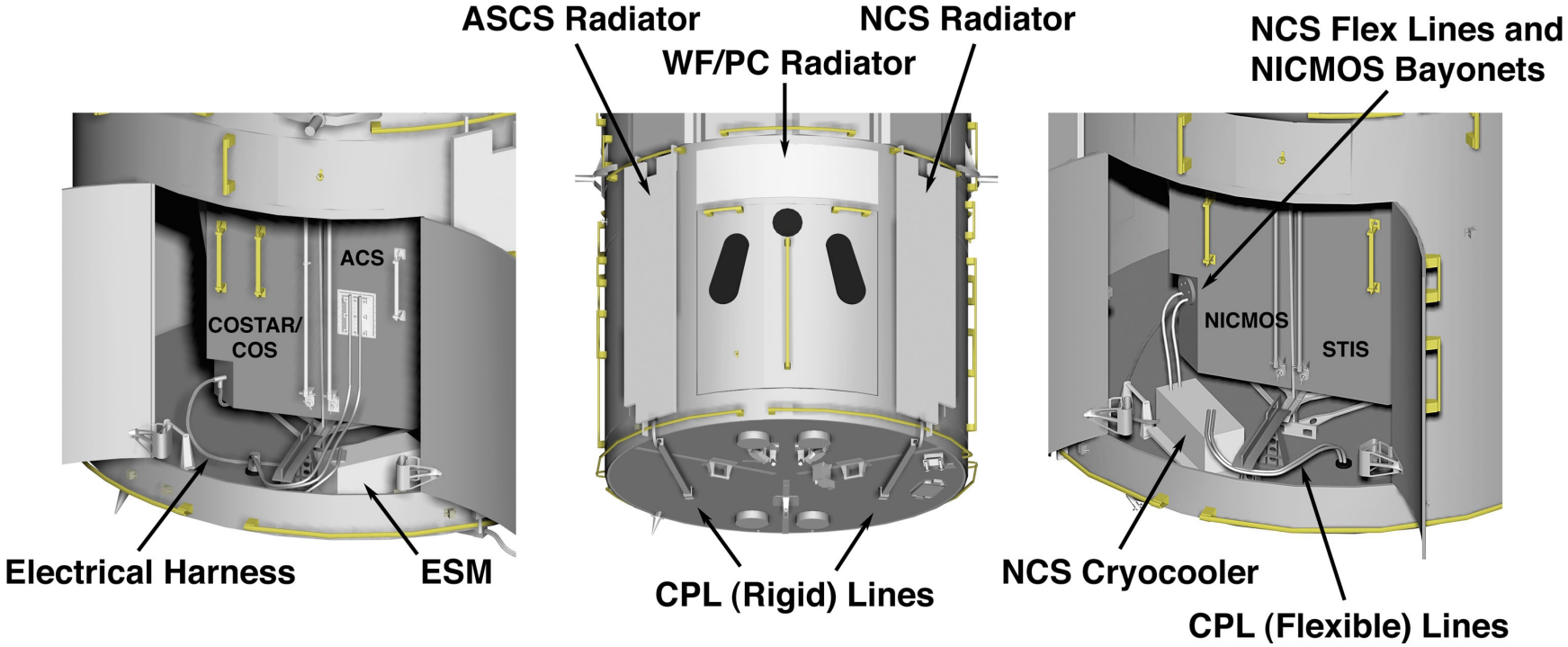
NICMOS Cooling System Components in the HST



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NICMOS Cooling System Components Description

- **The NCS cryocooler is attached to the HST Aft Shroud next to the NICMOS instrument.**
  - Two flexible pipes connect the cold Neon gas in the Circulator Loop to the NICMOS.
  - These pipes attach to two ground servicing cryogenic bayonets at the NICMOS.
- **The Electronics Support Module (ESM) is attached to the HST Aft Shroud next to the Advanced Camera for Surveys (ACS) instrument.**
  - Electrical connections to the NCS cryocooler are made with a Cross Aft Shroud Harness installed by the astronauts.
  - Power is provided from a connection to the COSTAR assembly.
- **The External Radiator is attached to handrails outside HST.**
  - Attached to the NCS cryocooler via the Capillary Pumped Loop.
  - Attached to the ESM for electrical control and monitoring.
- **The Aft Shroud Cooling System (ASCS) uses a second radiator that is to be installed during a future Servicing Mission.**
  - The hardware is fully qualified on the ground.
  - ESM control is already in place in the on-orbit hardware.

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NCS Deployment Experience

- **Prelaunch and Launch.**
  - All planned activities completed without incident.
  - Maintained vacuum pumping on the Circulator Loop components until door closure, and then the NCS was purged until T-0.
- **EVA.**
  - All planned activities completed without incident.
  - NCS installed and passed aliveness and functional tests.
  - External radiator is skewed a few degrees because of an interference between an MLI skirt and the HST (skirt stiffer than expected).
    - > Could have been fixed, but EVA time drove the decision to move on to other tasks.
- **Servicing Mission Orbital Verification.**
  - One transient turboalternator shutdown (by software) shortly after turn-on.
    - > No additional incidents.
  - Cooldown progressed (~2x) slower than expected.
    - > Discrepancies in modeling the heat extraction efficiency and heat capacity.
    - > Caused an extended period of “surging”.
    - > Vibration, even during surging, is negligible.
    - > NCS/NICMOS reached operating temperature after ~25 days.
    - > The instrument has been operational ever since.

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NCS On-Orbit Performance

	Parameter	Value	Unit
NICMOS	Detector Temperature	77.1	K
	Detector Temperature Stability	+/- 0.07	K
	Cryostat Cold Dome Temperature	~ 72.8	K
	Cryostat Parasitics	~ 0.4	Watts
Cryocooler	Cold Gas Temperature to NICMOS	~ 65	K
	Heat Rejection Temperature	278	K
	Total Cooling Power	6.5	Watts
System	External Radiator Temperature	-28 to -10	C
	NCS Power Consumption	375	Watts

All parameters meet specifications and are within expected ranges.

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The Restored NICMOS

- **NICMOS works better than ever.**
  - Detector quantum efficiencies increase with temperature.
    - > Original plan was 58K, driven by the solid Nitrogen cryogen.
    - > Actual operating temperature was ~ 62K with the cryostat thermal short.
    - > Current detector operating temperature is ~ 77K.
    - > An average of 30% increase in QE over the NICMOS bandpass.
  - Dark current still at or below the sky background level.
  - Readout noise is unchanged.
  - Instrument point-spread function is unchanged.
    - > Mechanical conditions inside the instrument appear unchanged.
  - In a typical faint object (m_{AB}=22 mag, 1 arcsec^2) at 1.6 um observed in NICMOS channel 2 (NIC2) for a typical time (1/2 orbit), the post-NCS data will have 30% more signal-to-noise than the pre-NCS data.
- **The proof is in the pudding.**
  - The ERO images confirm these expectations.

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NICMOS Operating Parameters

Parameter	Pre-NCS	Post-NCS	Units	Comments
Readout Noise	~30	~30	e^-/readout	Unchanged.
Dark Current	0.1	~0.15	e^-/pix/sec	
QE (F110W)	0.2	0.32	QE = quantum efficiency. F110W is short wavelength end (1.1 um) for NICMOS, F222M is long wavelength (2.2 um) end.	
QE (F160W)	0.3	0.42		
QE (F222M)	0.6	0.72		
Focus	See next chart.			Unchanged.

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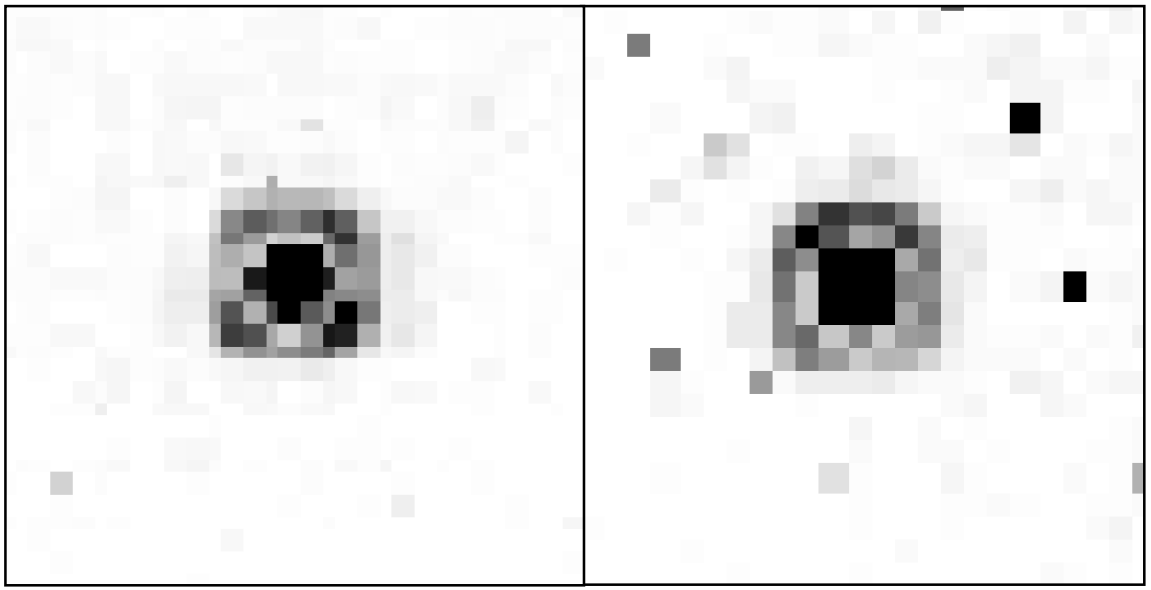
NICMOS Focus is Better Than Ever



1.1 um (NIC1) 1.6 um (NIC2)

The restored NICMOS has a point spread function that demonstrates diffraction-limiting imaging. The image on the left is taken with the highest resolution channel (NIC1) at 1.1 um. The image on the right is with the medium resolution channel (NIC2) at 1.6 um. Both images clearly show the sharp central core of a star and the first diffraction ring.

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Conclusion

- **All components installed in March 2002 during Servicing Mission 3B are now fully operational.**
  - 100% servicing success.
  - 100% deployment success.
- **Hubble now enjoys twice the electrical power for science compared with pre-SM3B.**
  - A combination of the new Solar Arrays and Power Control Unit.
- **Hubble users have a powerful new visible camera (ACS).**
- **Hubble users have a restored and improved near-infrared capability (NCS/NICMOS).**
- **The outlook for new discoveries is better than ever.**

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To Follow Hubble's Continuing Story …

- **http://hubble.nasa.gov/project-news/press-kits.html**
  - This information package is available in PowerPoint or PDF using this link.

- **http://hubble.nasa.gov**
  - General information about the Hubble Space Telescope.
  - Up-to-the-minute information during Servicing Missions.
  - Live web cameras in HST clean rooms and control areas.
  - Q&A for the HST Team during Servicing Missions.
  - Extensive mission coverage during Servicing Missions.

- **http://www.stsci.edu**
  - All the Hubble pretty pictures are available here.
  - This is the general scientific observation support site for the international scientific community.

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