NASA Cryocooler Development Program Overview

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http://www.jpl.nasa.gov/adv_tech/coolers/summary.htm

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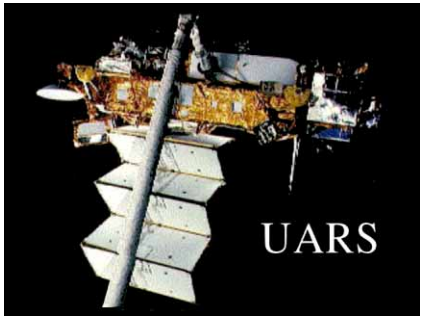
Topics

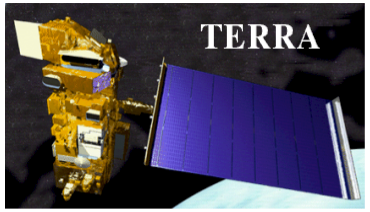
- Background
  - History of NASA cryocooler missions
  - Space cryocooler flight operating experience
- Planck sorption cooler
- DoD large capacity 35K/85K two-stage cryocoolers
- NASA ACTDP cryocooler development program
  - Objectives and Requirements
  - Contractors and Concepts
- Example application of ACTDP cryocoolers to 4-6 K cooling of a large space observatory
  - JWST/MIRI cryocooler integration concept
  - Cooling capacity versus temperature
  - Predicted in-space cooldown time for MIRI
- Summary

Background

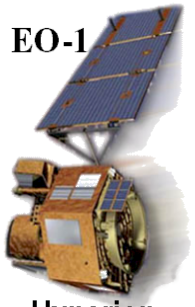
- Cryocoolers are an enabling technology for many NASA space-science missions
- NASA first flew long-life cryocoolers on UARS in 1991 (British ISAMS instrument); this started the history of the very successful "Oxford cooler" designs



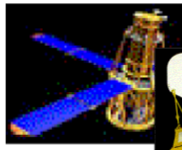
- NASA has now put nine more long-life coolers into flight service including four in 2002, and three more are scheduled for launch on the Aura spacecraft this month



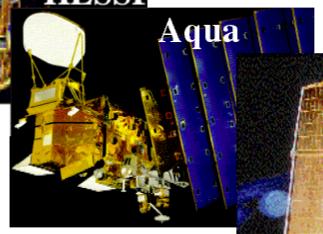
ASTER (2)
MOPITT (2)



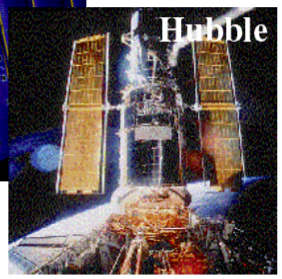
Hyperion



RHESSI



AIRS (2)



NICMOS

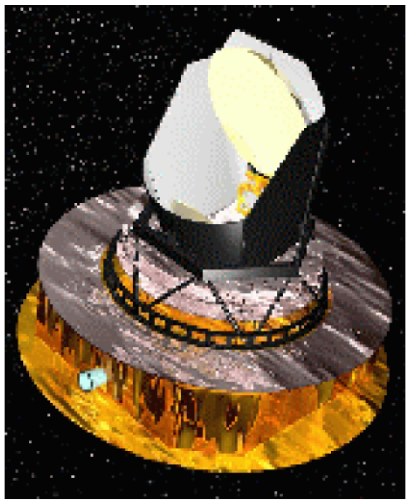
HIRDLS (1)
TES (2)

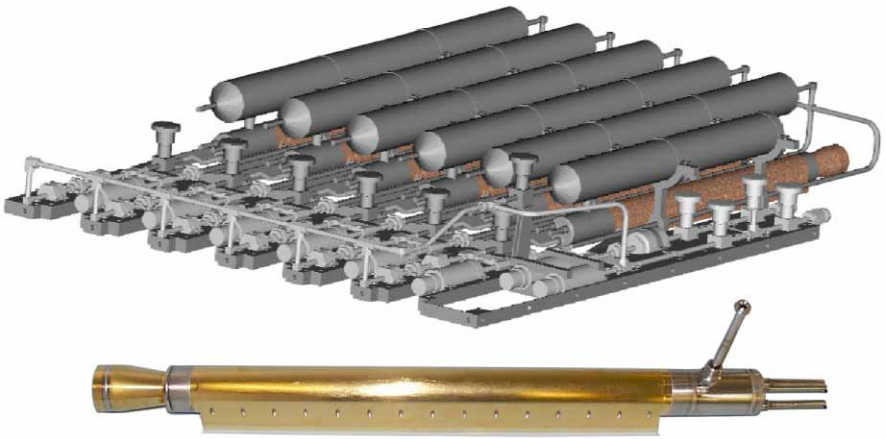
Space Cryocooler Flight Operating Experience

Cooler / Mission	Running Hours	Comments
Creare Turbo Brayton		
NICMOS	19,000	As of 5/04, Ongoing, No degrad.
Japanese Stirling		
ASTER (2 units)	37,000	As of 5/04, Ongoing, No degrad.
NGST (TRW) Pulse Tubes		
CX (Mini PT (2 units))	57,000	As of 5/04, Ongoing, No degrad.
MTI (6020 10cc PT)	37,000	As of 5/04, Ongoing, No degrad.
Hyperion (Mini PT)	30,000	As of 5/04, Ongoing, No degrad.
SABER (Mini PT)	24,000	As of 5/04, Ongoing, No degrad.
AIRS (10cc PT (2 units))	18,000	As of 5/04, Ongoing, No degrad.
Oxford/BAe/MMS/Astrium Stirling		
ISAMS (80 K Oxford)	16,223	Near continuous 10/91 thru 7/92
HTSSE-2 (80K BAe)	24,000	Mission ended 3/02, No degrad.
INTEGRAL (50-80K Astrium (4))	13,000	As of 5/04, Ongoing, No degrad.
MOPITT (50-80K BAe (2 units))	37,000	As of 5/04, one displacer failed at 11,000 hours; other still running
RAL 80K Integral Stirling		
ATSR 1	42,000	Near continuous 7/91 thru 6/96
ATSR 2	~74,000	As of 5/04; launched 5/95; No degrad.
Sunpower Integral Stirling		
RHESSI	20,000	As of 5/04, Ongoing, No degrad.

Planck Sorption Cooler

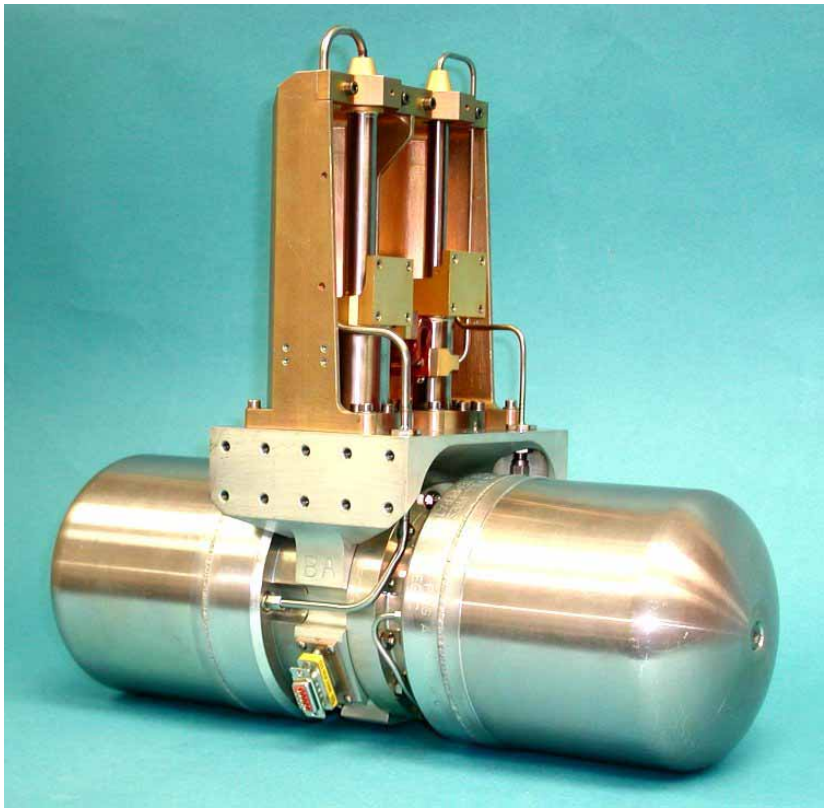
- Planck mission of the European Space Agency
  - Very high resolution mapping of temperature anisotropy in the CMB (2007 launch)
- Two JPL hydrogen sorption cryocoolers
  - Cool the LFI detectors to 18 - 20 K
  - Precool RAL 4 K helium J-T for HFI system
  - Deliver flight units in Nov. 2004 and April 2005





Large SBIRS Cooler

- DoD Missile Defense Agency missions desire large cooling capacities:
  - 2 W at 35 K ...plus
  - 20 W at 85 K
- Large "Oxford style" pulse tube cryocoolers have been developed at NGST and Lockheed Martin for this need with input power capacities up to 600 watts
- These large-capacity coolers provide near-flight-qualified hardware for future NASA missions to build upon

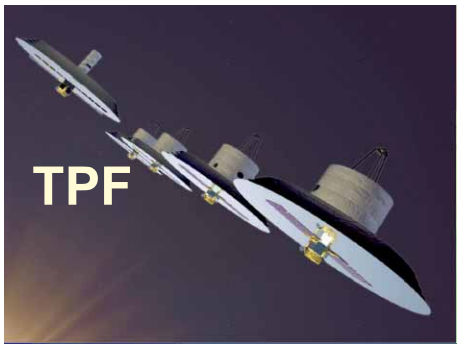


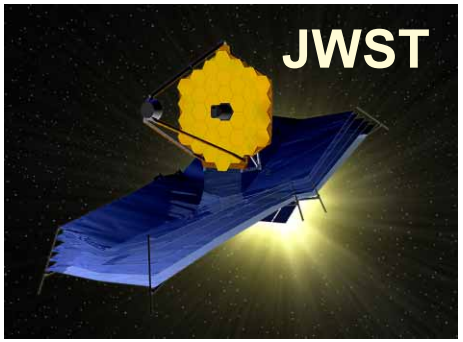
NGST (TRW) HCC 35K/85K
2-stage pulse tube cryocooler
(14 kg, 600 W)

ACTDP Objective

(Advanced Cryocooler Technology Development Program)

- Cryocooler development for next generation space-based observatories
  - 4-6 K / 18 K two-stage cooling
  - Remote coldheads (on deployable structures)
  - Minimal generated noise (EMI and Vibration)
- Three key missions have served as focus
  - Terrestrial Planet Finder
  - Constellation-X
  - James Web Space Telescope
- Designed to provide proven Development Model (DM) coolers in the 2006 timeframe

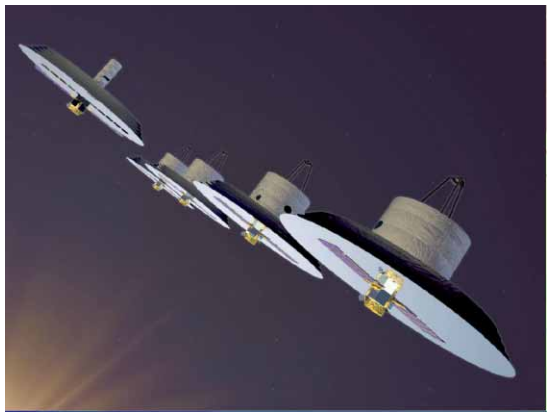




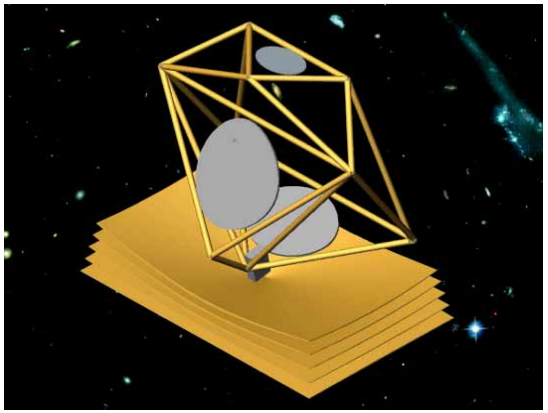
Top-Level Requirements

Consensus Top-level cooler requirements for TPF, JWST, and Con-X have been identified and reflected in a detailed ACTDP cryocooler specification. Key requirements include:

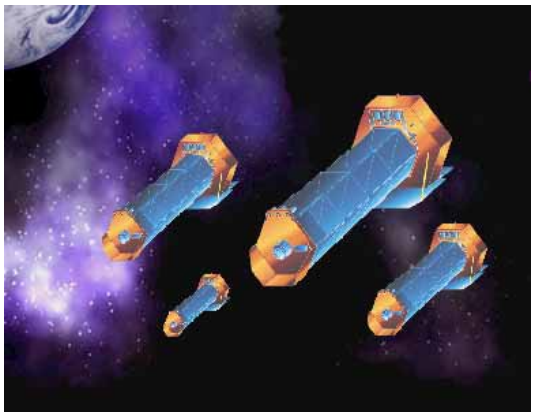
- **30 mW at 6 K *plus* 150 mW at 18 K**
- **<200 watts input power**
- **< 40 kg cooler system mass**
- **Accommodate 5 to 25 meter cold-end deployment length**
- **Low Generated Vibration and EMI, 10 year life**



TPF

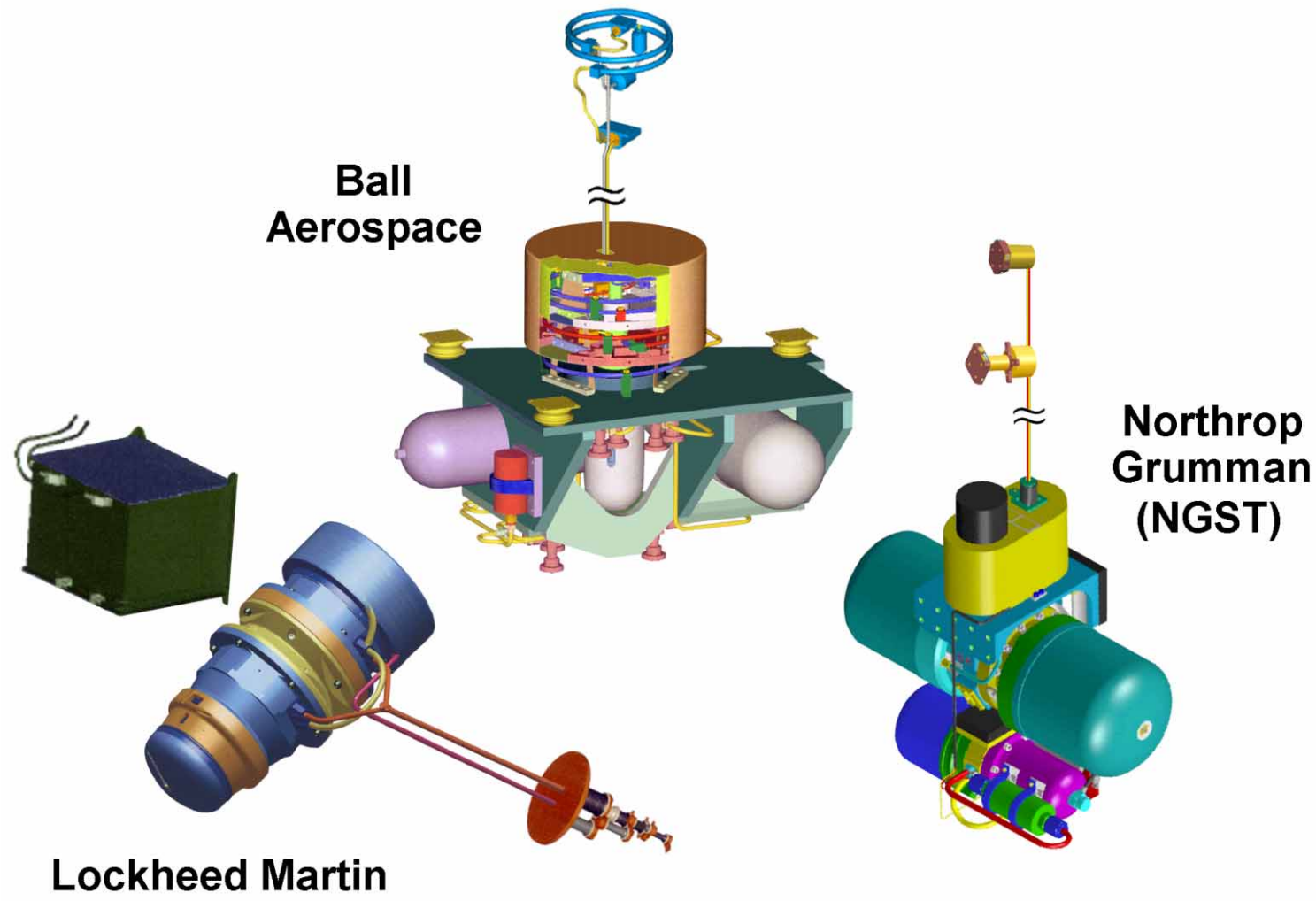


SAFIR

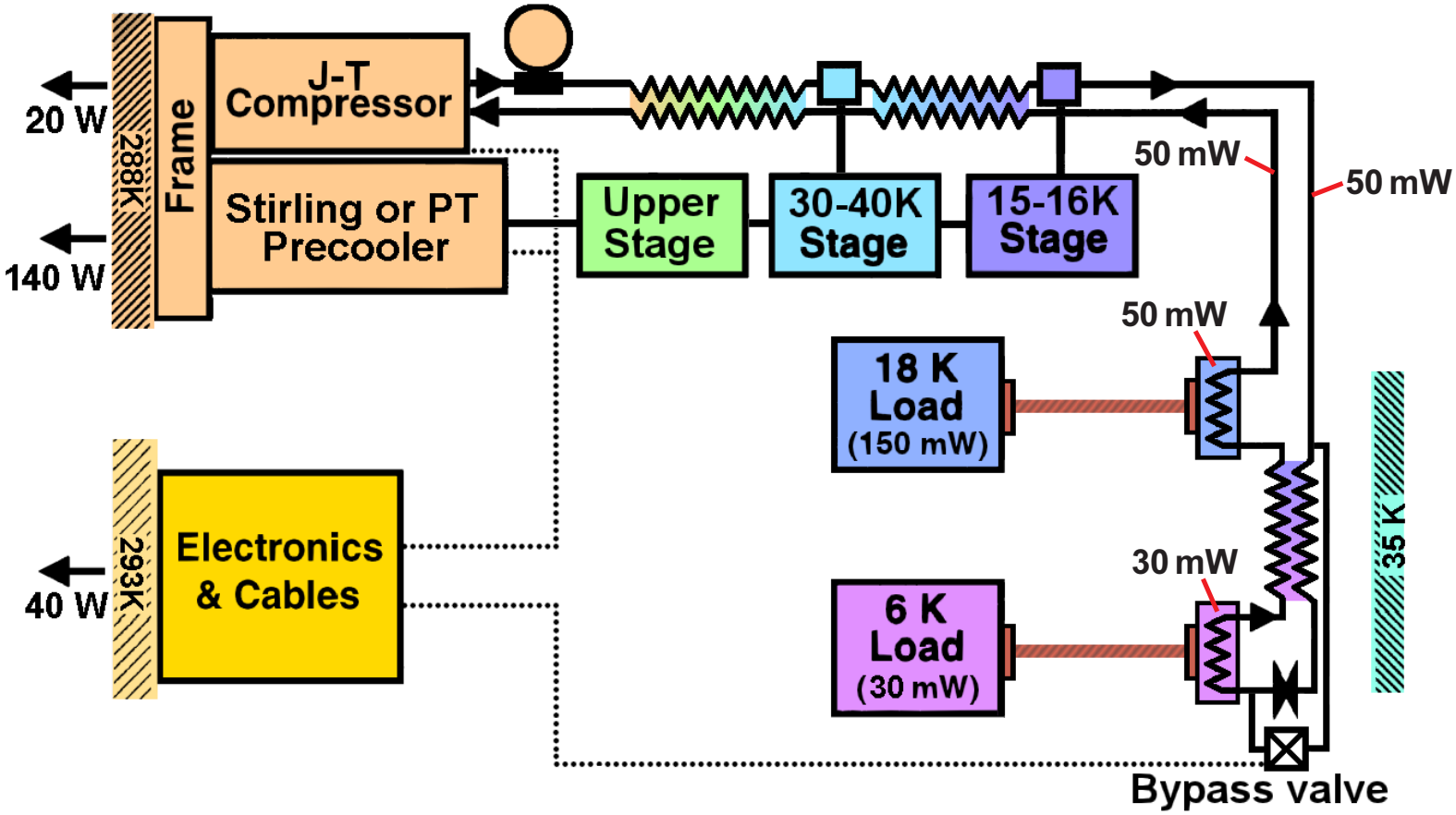


Con-X

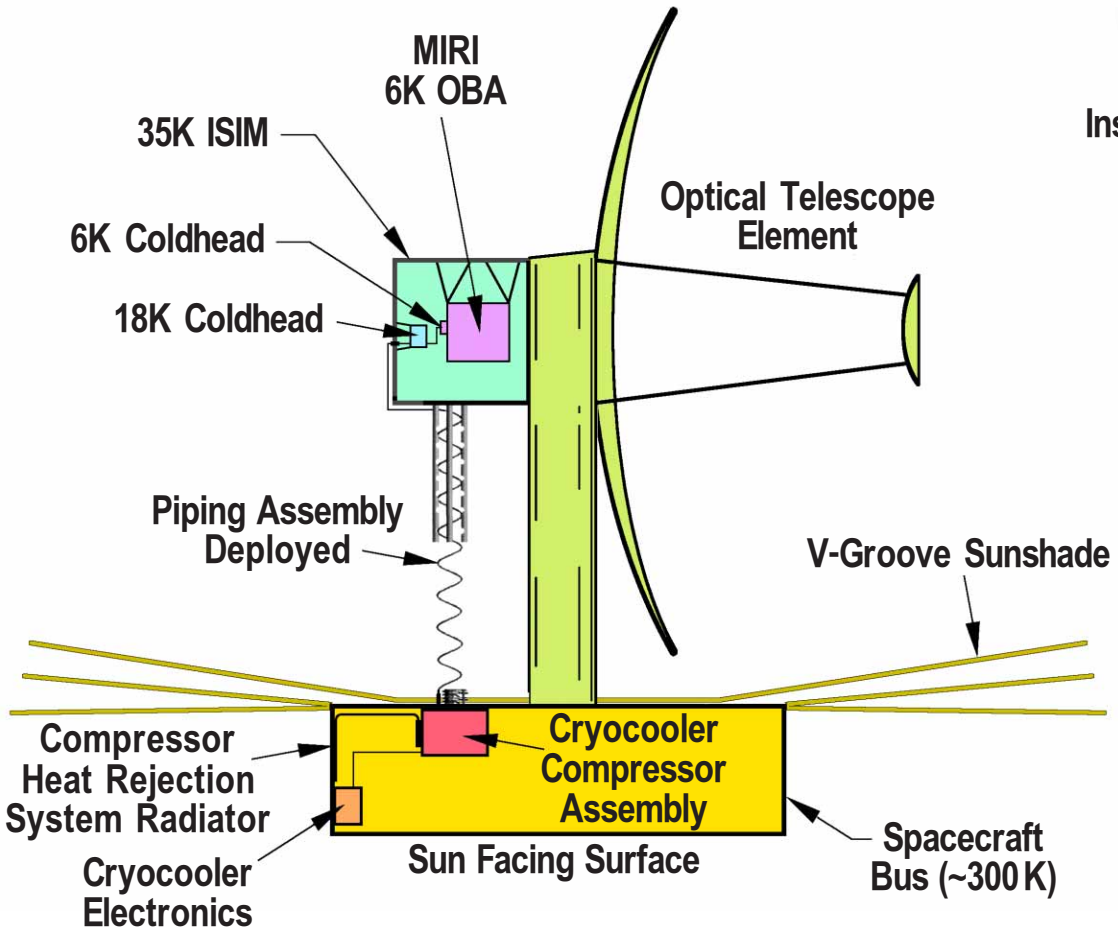
ACTDP Cryocooler Contractors and Concepts

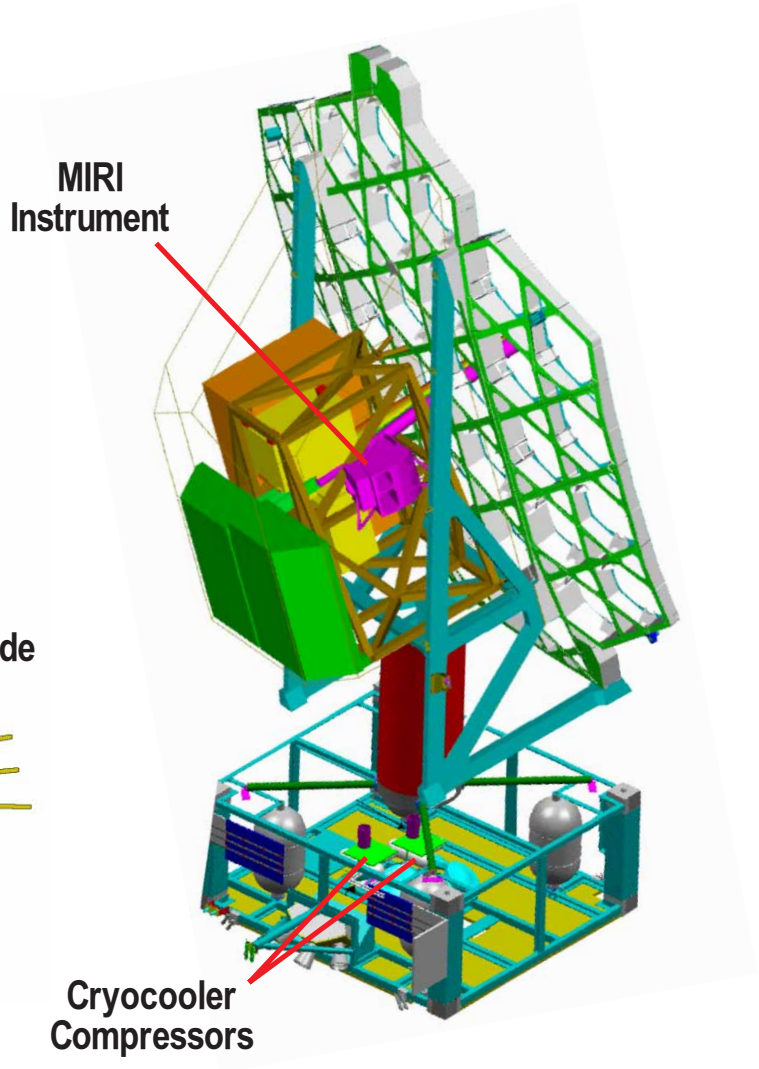


ACTDP Hybrid J-T Cryocooler Thermal Flow Diagram

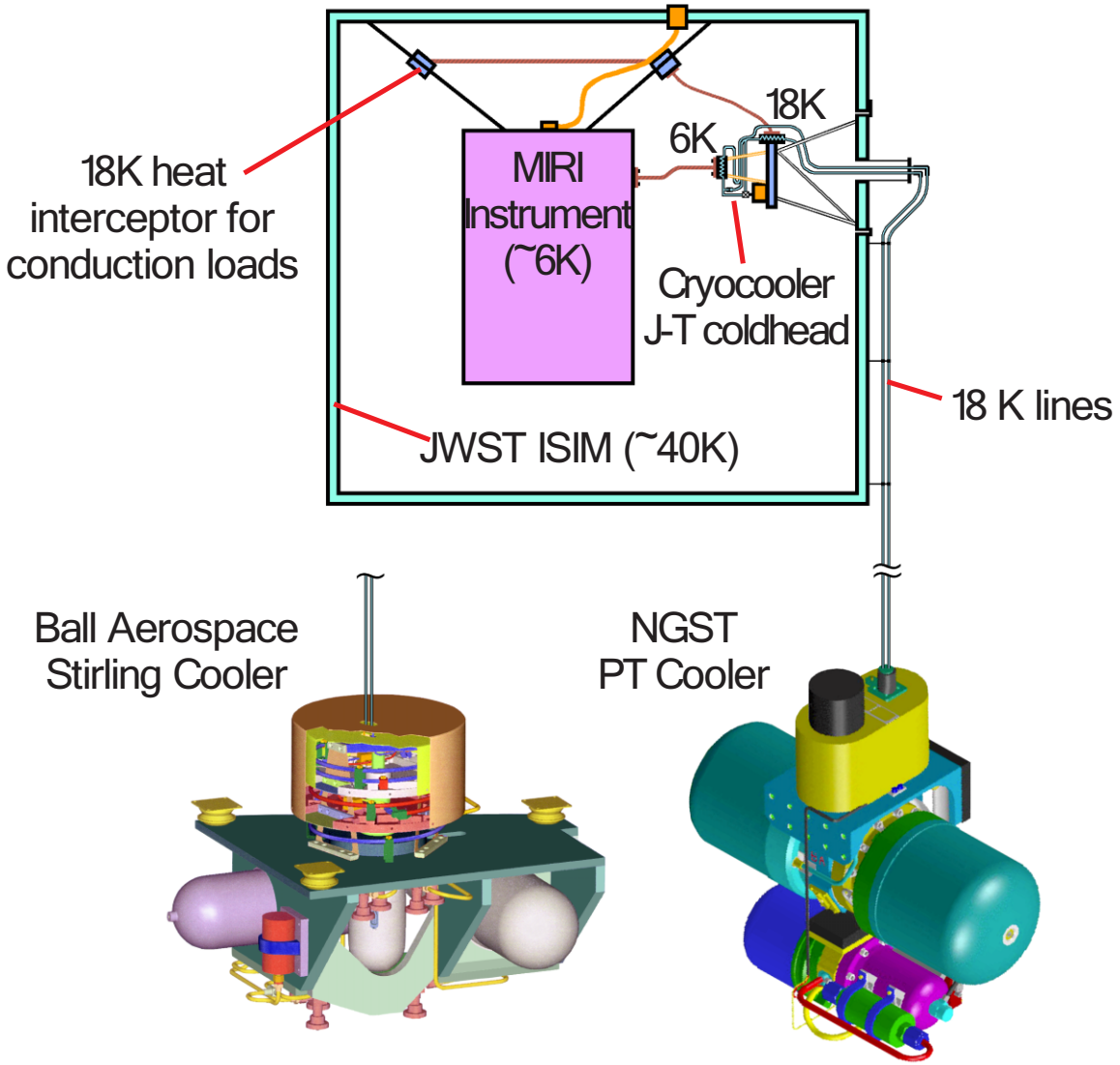


Example Cryocooler Application to James Webb Space Telescope

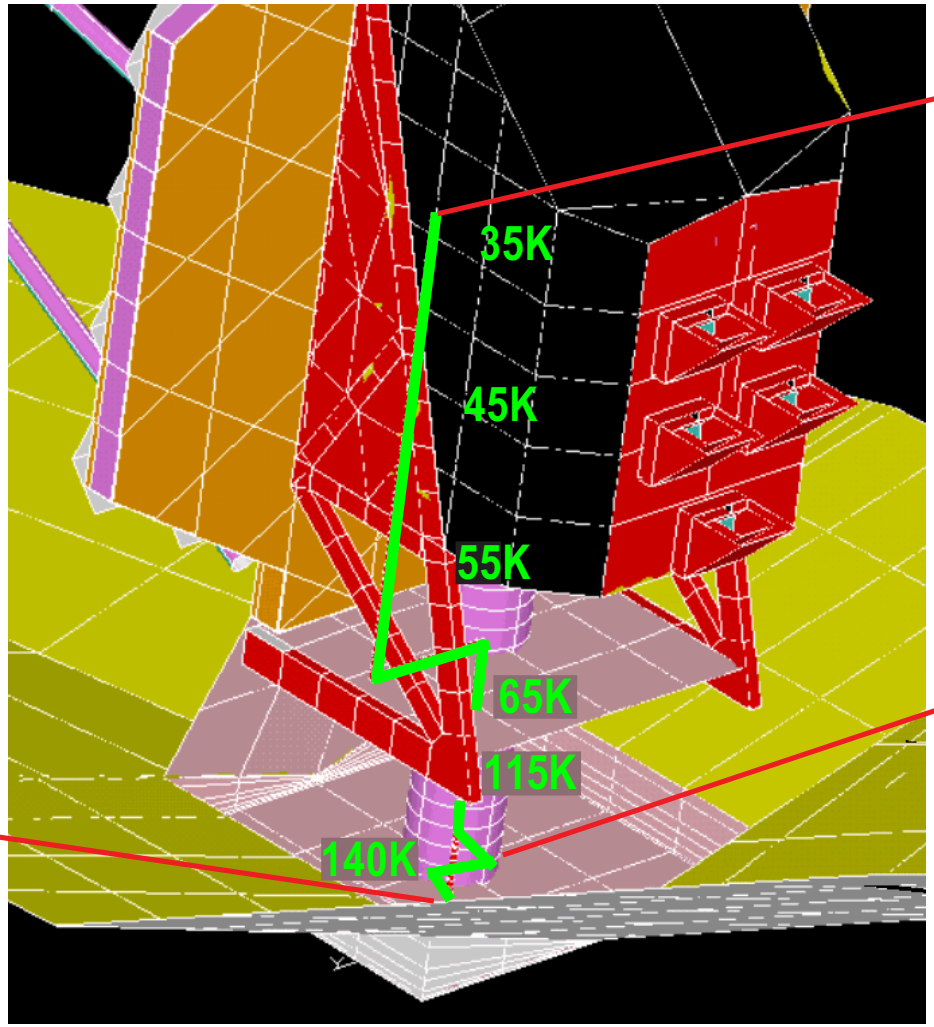




Example MIRI Instrument Cryocooler Integration Concept



MIRI Cryocooler Piping Assembly Thermal Boundary Conditions



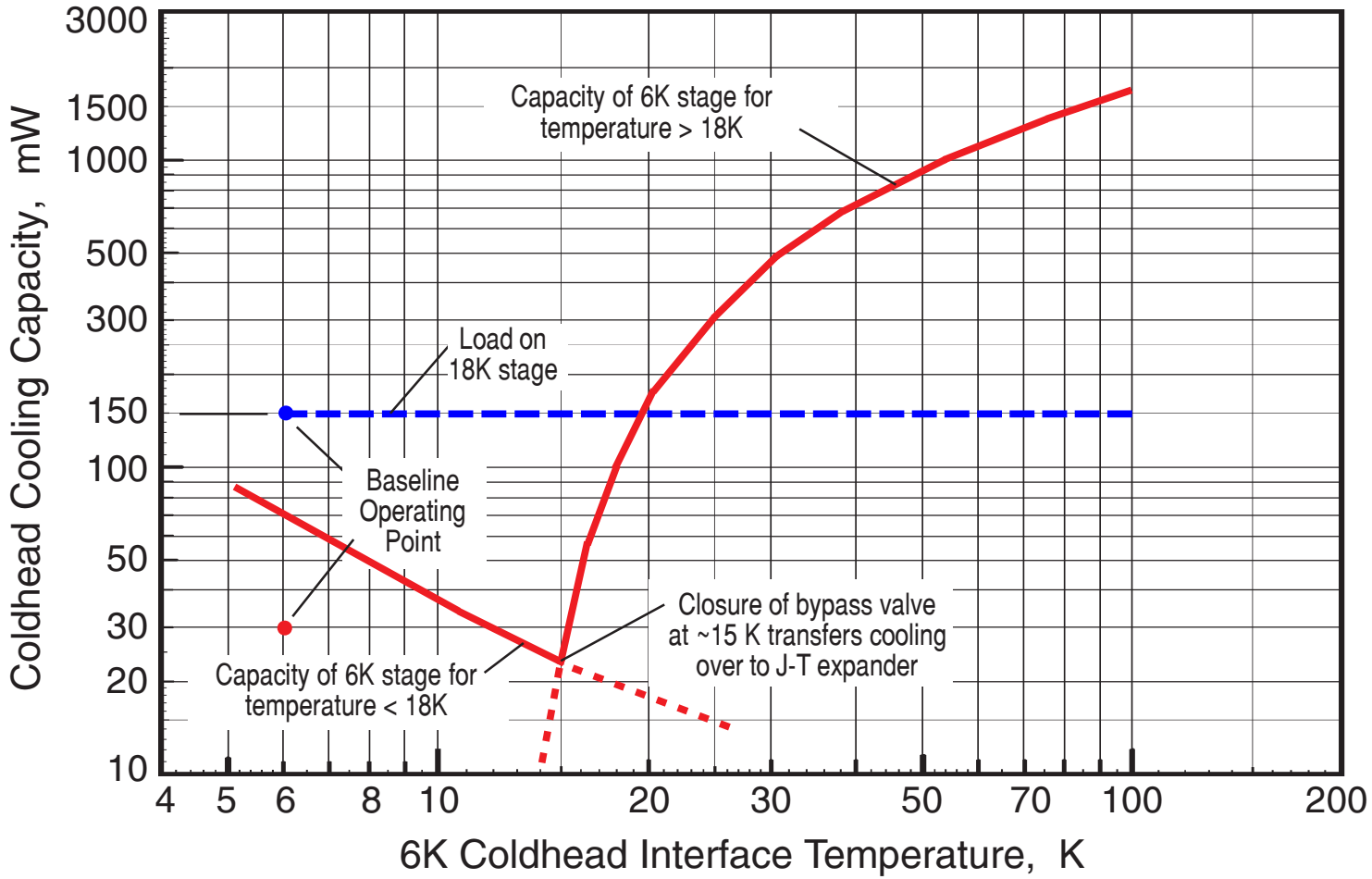
Disconnect fitting (35K)

Total length ~10m

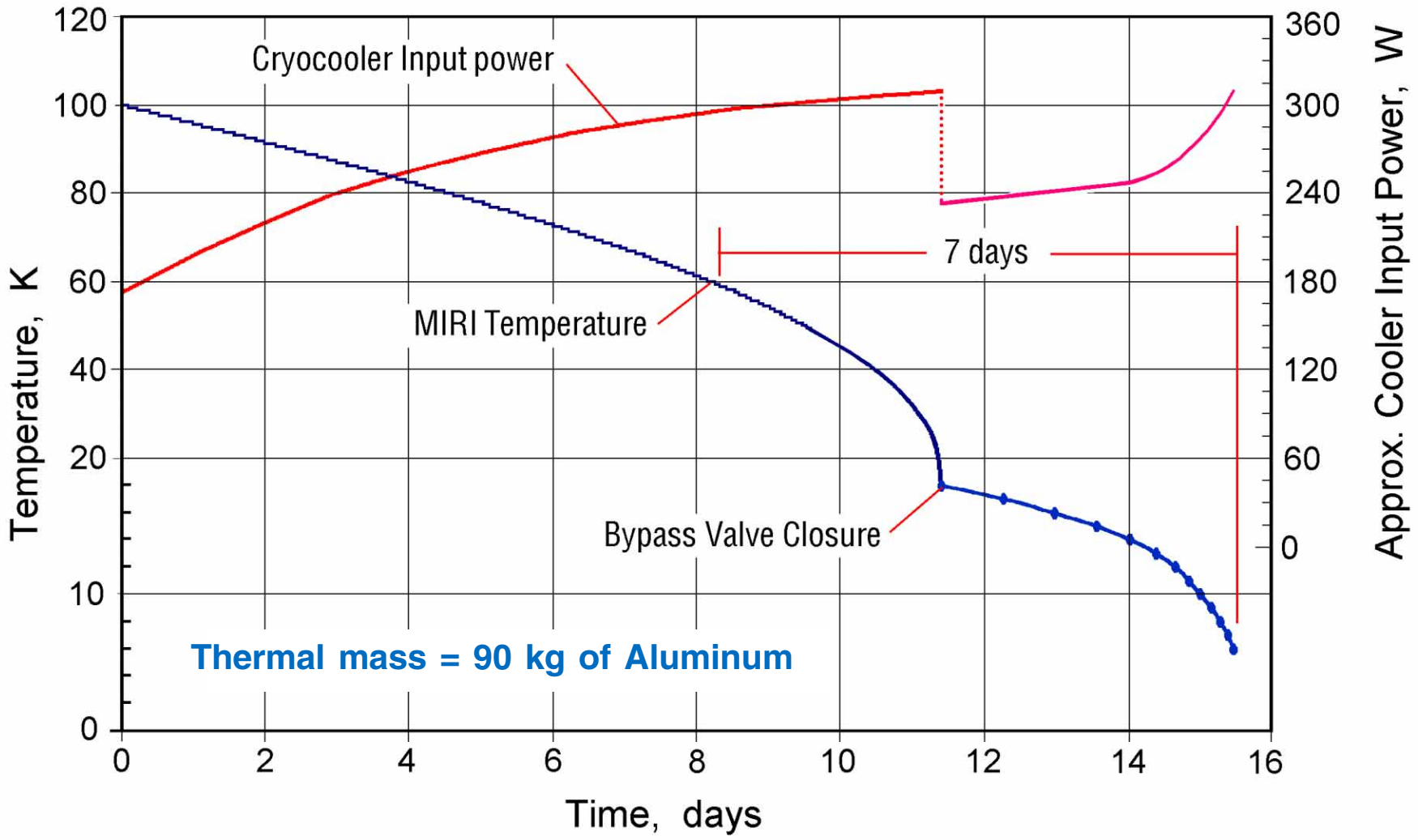
Deployment section (118 K)

Disconnect fitting (145 K)

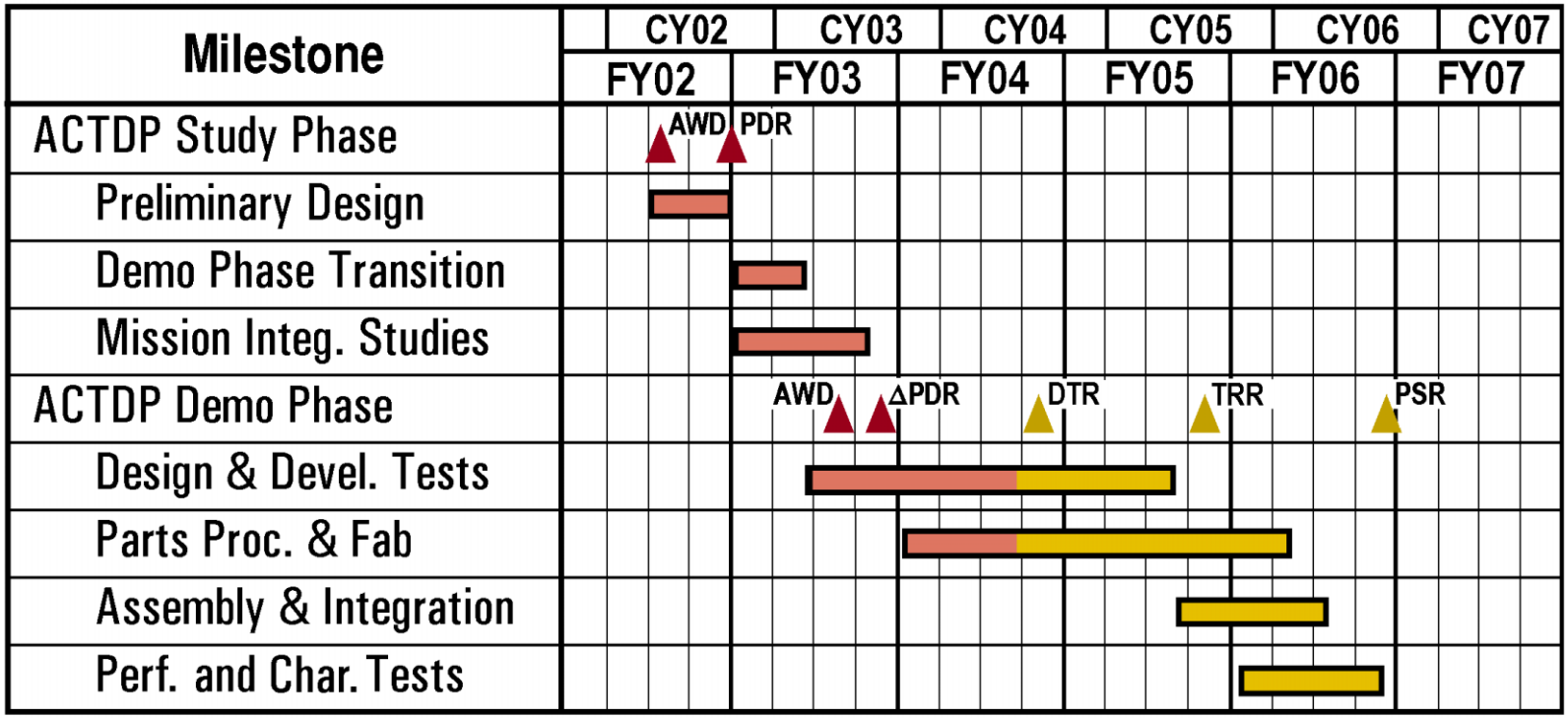
ACTDP Hybrid J-T Cryocooler Cooling Capacity vs Temperature



MIRI Cooldown vs Time Using an ACTDP Cryocooler



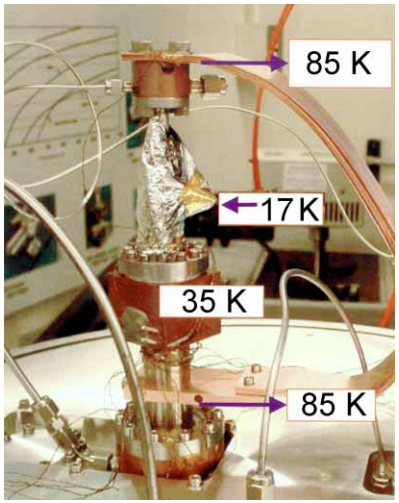
Procurement Schedule



DTR = Development Test Review
TRR = Technology Readiness Review
PSR = Pre-ship Review

Project Status

- Three teams were selected in January 2003 for Demo-Phase contracts and have completed detail designs at this point:
  - Ball Aerospace, Boulder Colorado
  - NGST (TRW), Redondo Beach, California
  - Lockheed Martin, Palo Alto, California
- Current effort is on design refinement and development testing at testbed level to achieve efficiency and life goals
- Development Test Review scheduled for this summer and Technology Readiness Review is scheduled for summer 2005.
- Assembly and test of complete Development Model coolers at systems level is scheduled for completion by summer 2006



Summary

- Space cryocoolers have reached a high level of maturity
  - Life times in excess of 10 years in ground tests
  - Over 20 coolers operating in space with multi-year lifetimes
  - Two more cooler missions are scheduled for launch this summer
- Present NASA development emphasis is on 4-6K / 18K coolers to enable the use of low-temperature detectors and optics with future multi-year observatory missions; the coolers are being developed as part of the Advanced Cryocooler Technology Development Program (ACTDP)
- Development Models of these new ACTDP coolers are currently in the detailed design and test phase as part of the TPF project; system-level demonstrations of these DM cryocoolers are scheduled for summer 2006