FIR Technology Development

What Technologies Do We Need for Future (Space) Far-Infrared Astronomy?

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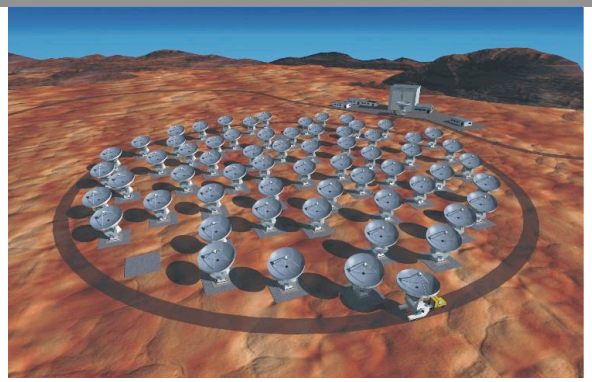
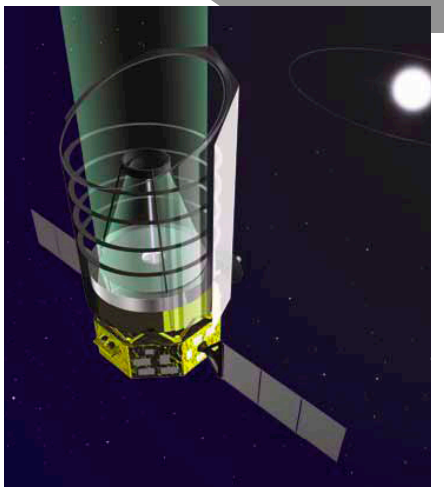
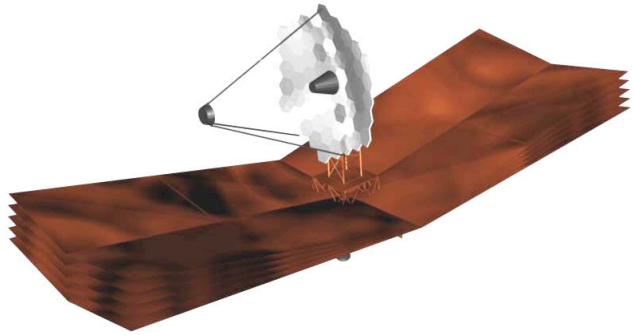
Missions & Facilities I

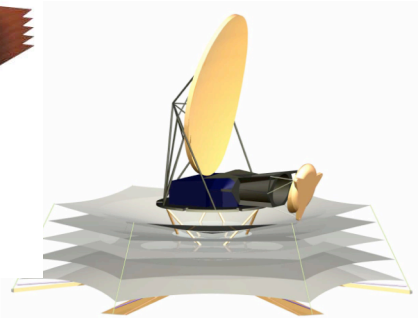


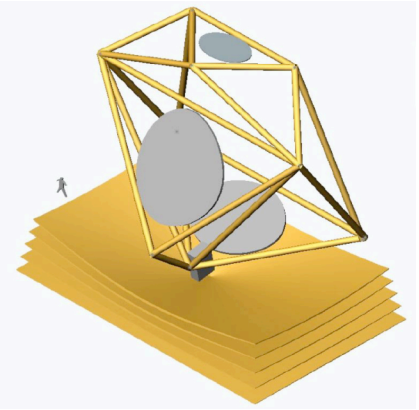


- BLAST (Devlin)
- SOFIA (20-22; Becklin, Benford, and Radford)
- SPICA (23-27; Nakagawa, Sugita, Bradford, Isaak, Tamura)
- ALMA (28; Wootten)
- Square Kilometer Array (29; Lazio)

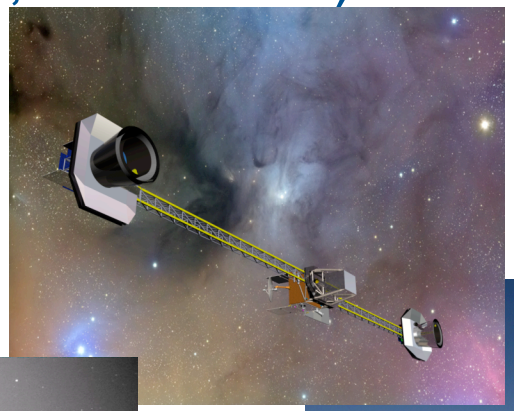
The Unicorns







- SAFIR / CALISTO (30-32, 42; Lester, Goldsmith)
- SPIRIT (33; Leisawitz)
- CCAT (34; Radford)
- BETTII (35; Rinehart)
- Far-IR Survey mission (e.g. SIRCE)



Technologies, Prioritized (?)

Technology (unique-ish to the FIR)

- Detectors
  - Homodyne (Bock, 38-41; Billot, Kenyon, Day, Echternach)
  - Heterodyne (Zmuidzinas)
- Cryocoolers
  - Subkelvin (36, Paine)
  - Instrument/Telescope cooling (Nakagawa)
- Cryo-Mechanisms (Lawson, 37; Silverberg)
- Cryo-Optics (Stahl)
  - Filters/Dichroics/Combiners

Broad Technology Needs

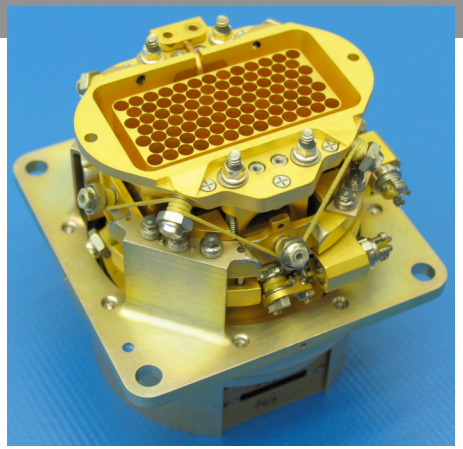
Technologies needed more broadly:

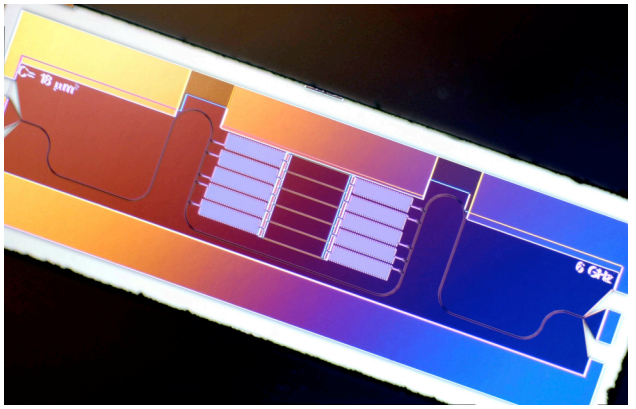
- Metrology (Lawson)
- Modelling
- Large Structures
- Integration & Testing
- Formation Flying (Lawson)

Missions & Technologies

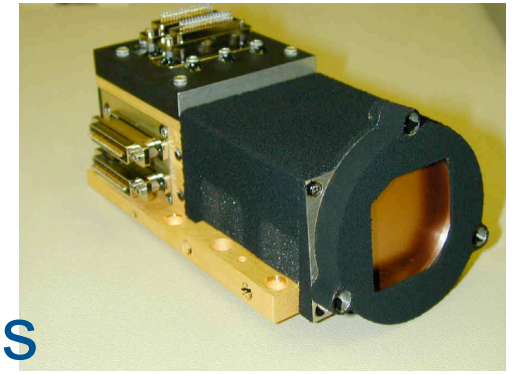
	Detectors: Homodyne	Detectors: Heterodyne	Subkelvin Coolers	Cryocoolers (Large)	Mechanisms (cryo)	Cryooptics	FIR Filters	Metrology	Structures	Integration & Test
SAFIR		?								X
SPIRIT										X
CCAT	?									
BETTII										
SIRCE				?	?					

Detectors: Homodyne





- TES bolometers
- MKIDs
- Photoconductors
- QCD (Quantum Capacitor)
- QWIP/QWISP

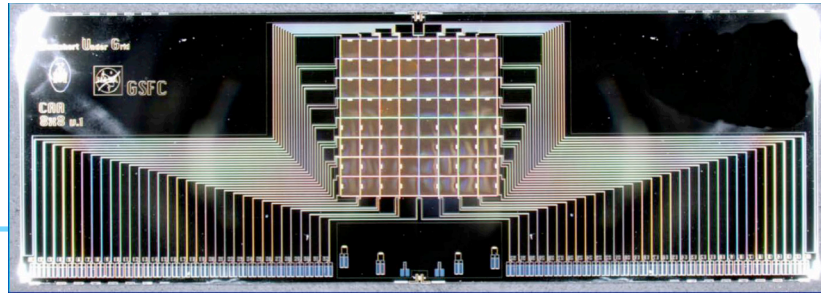


Important elements:

- Sensitivity
- number of pixels
- filling factor

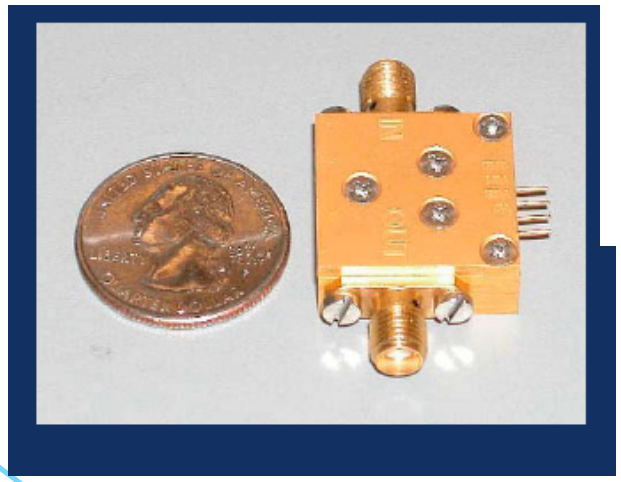
–Speed

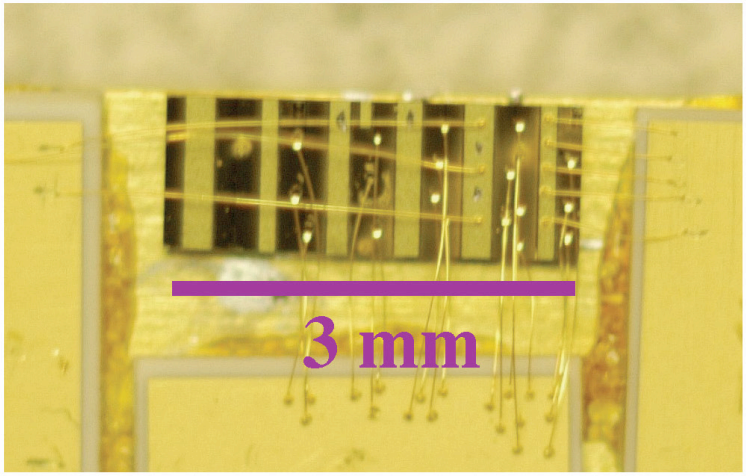
–unique peculiarities



Detectors: Heterodyne

- FIR receivers (THz) can be made significantly better than Herschel HiFi
  - Frequency range
  - Sensitivity



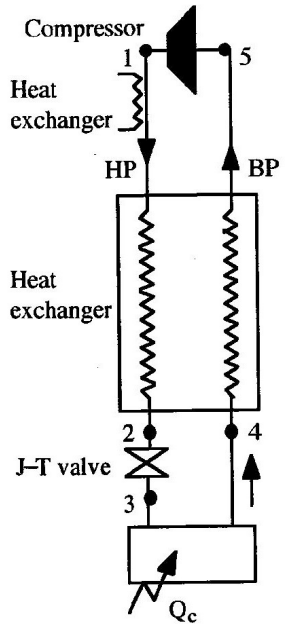


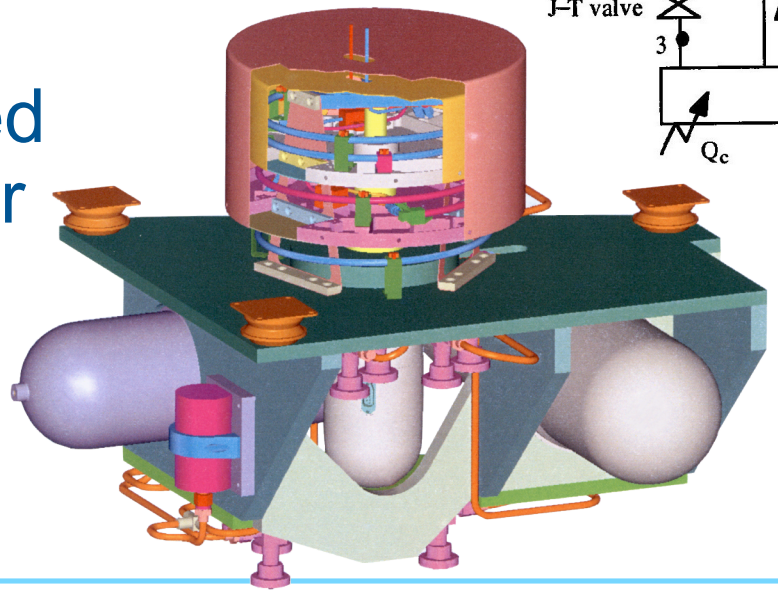
Cryocoolers

Cryocoolers needed for long life of future missions

- Joules-Thomson coolers on JWST, Planck, etc.
- Stirling 2-stage on Akari

Continued development needed to provide maximum cooling for minimum weight, power, and complexity.



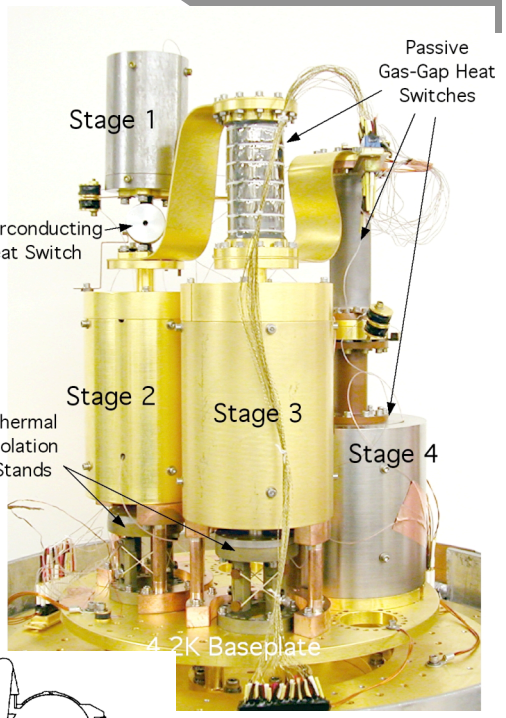


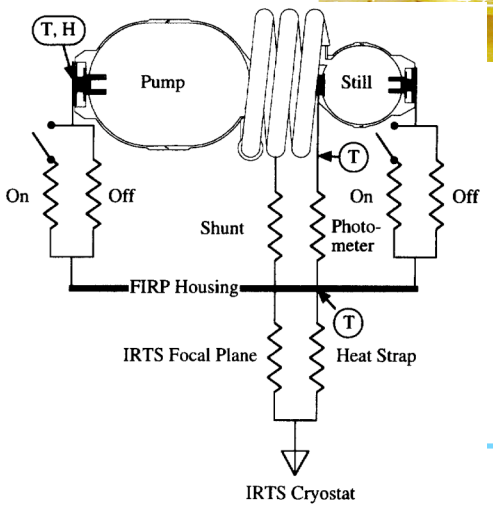
Subkelvin Coolers

Subkelvin coolers have been demonstrated (overlapping need between the FIR and the X-ray astronomy communities)

- ADR: Suzaku
- ^{3}He Coolers: IRTS, Herschel

May need more stages to lower detector temperatures





Cryooptics

Making big mirrors is becoming “easy”.
Making them light still a challenge

- SPICA will demonstrate cold SiC mirror
- Major challenges not optical:
  - Support structures
  - Cooling
- Validation via cryotesting
- Testing of large systems may be difficult/impossible.

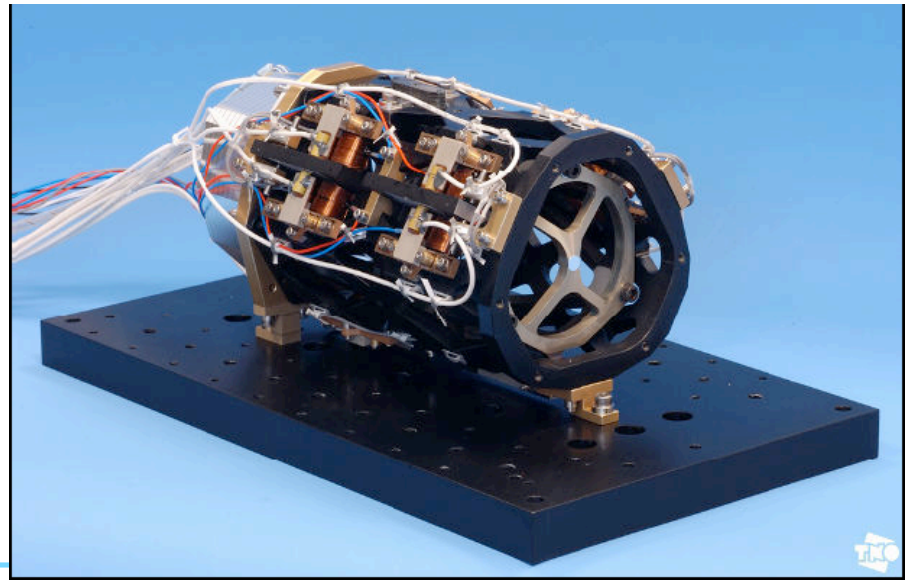
Mechanisms

Cryomechanisms have a long history. Millions of cycles of FTS on COBE.

Most missions will need at least one cryomechanism. Particular challenges include:

- Accurate & smooth delay lines for interferometry
- Trolleys for boom interferometers

Shared with TPF-I



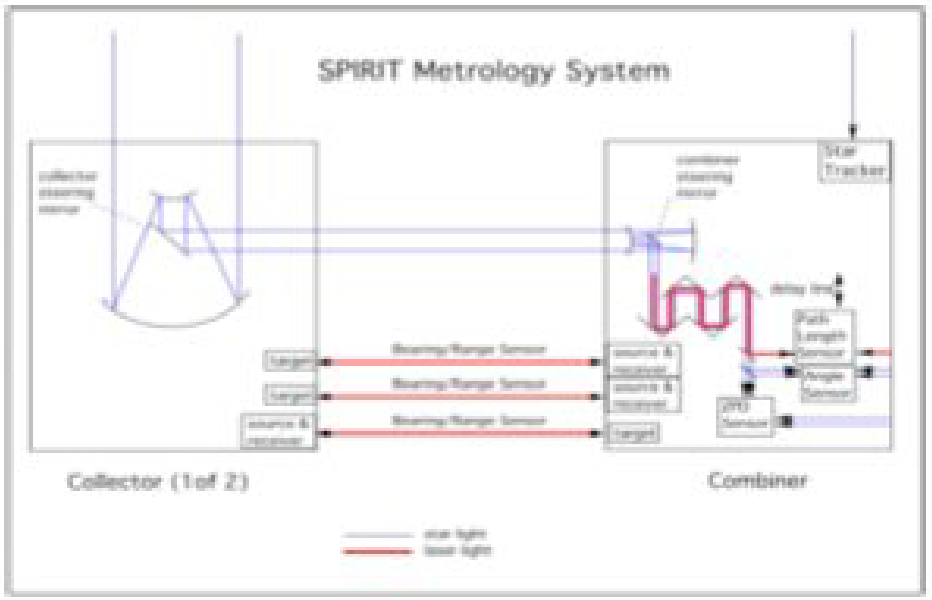
FIR Filters

Future missions will need high-quality FIR filters

- Wiregrid filters from Cardiff currently SOA
- New work in the US on making high-quality FIR filters (NRL)

Metrology

- Metrology systems for single apertures developed for JWST (overkill for a deployed SAFIR)
- Metrology systems for interferometers developed (or in development) for SIM and TPF-I (overkill for FIR interferometers)



Structures

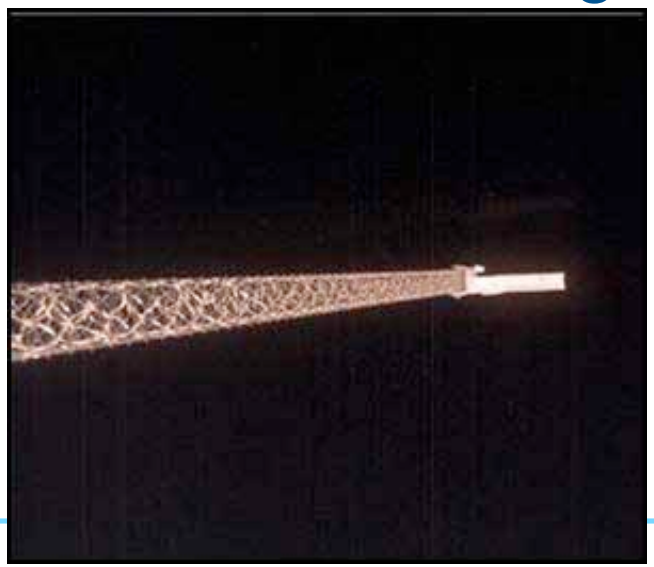
Nearly all future large missions require deployments.

- Sunshades
- Segmented mirrors
- Booms for interferometry

JWST has demonstrated some of these methodologies.

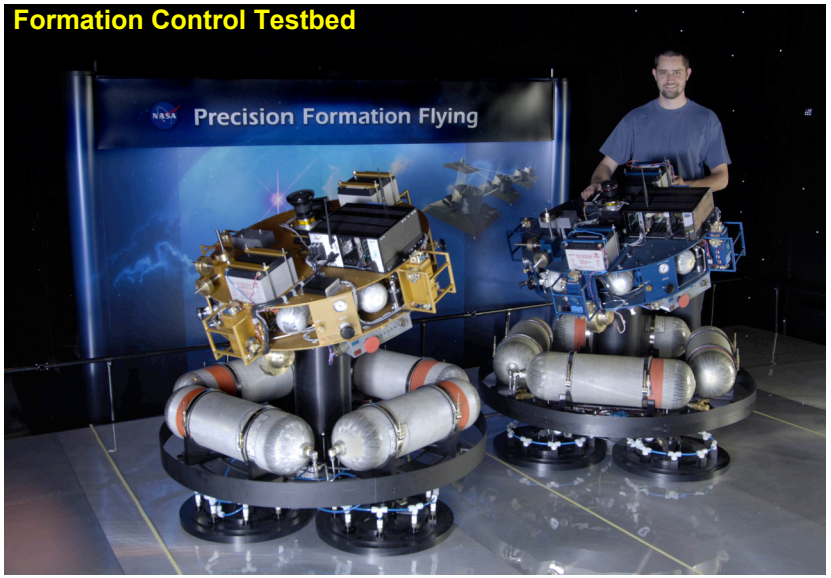
Booms deployed from shuttle,

Mars Express.



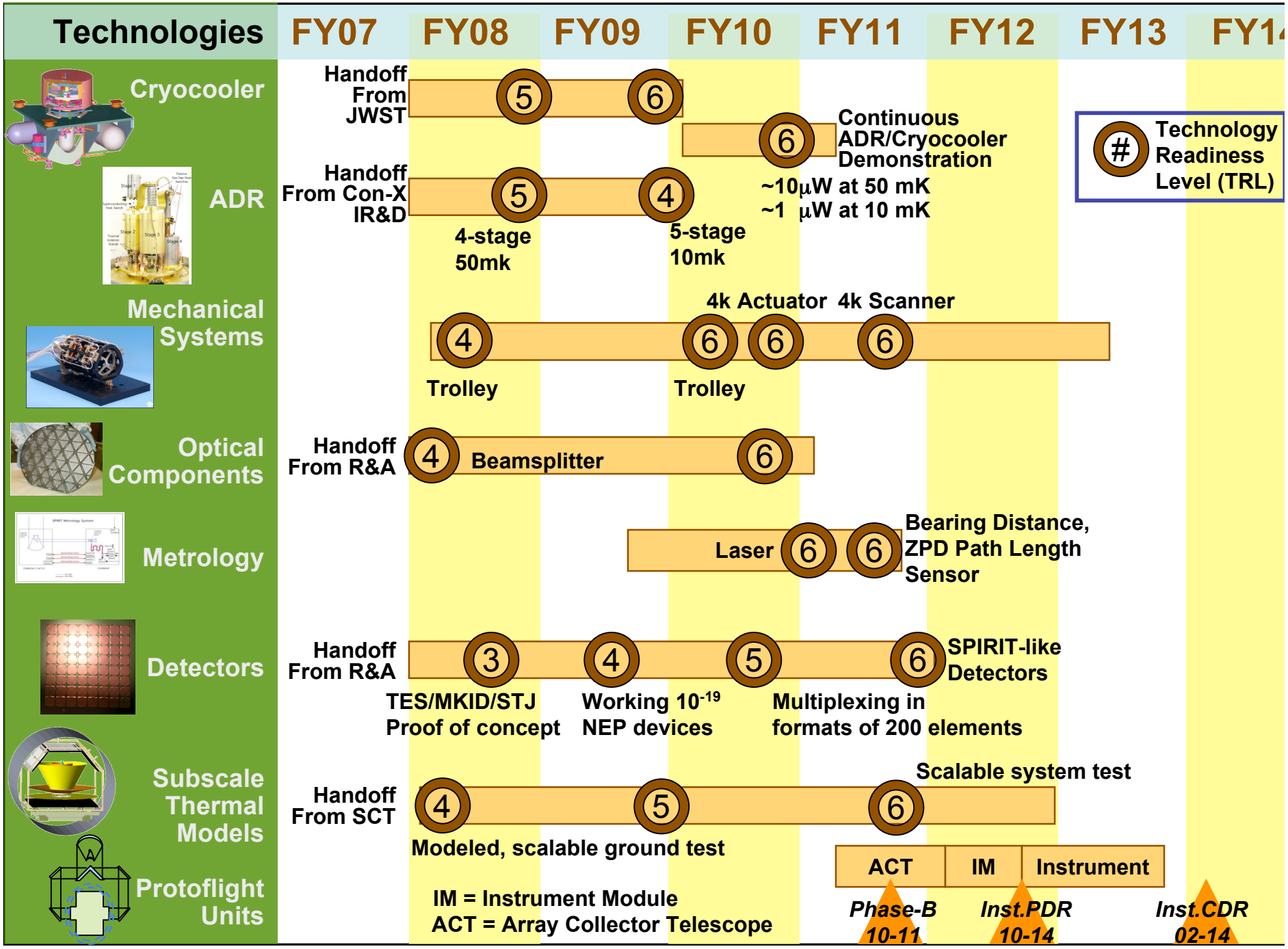
Formation Flying

None of the near-term FIR missions require formation flying. However, developments for TPF-I may be of value for new future incarnations of SPECS.



Ares V and Servicing

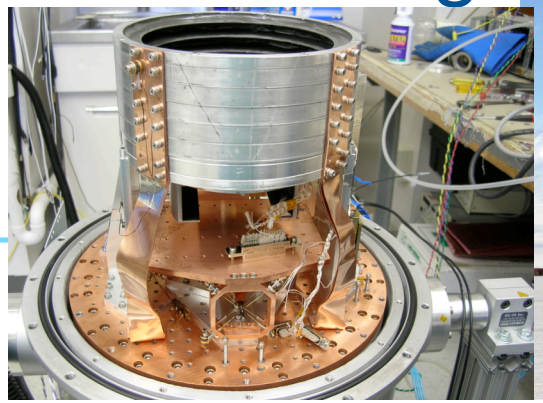
- Ares V is coming.
  - How can we take advantage of it?
  - Monolithic apertures cheaper than deployed (?)
- Serviceability?
  - Refueling? Instrument change-out?
  - Cryocoolers need to be designed for long life (closed-cycle)
  - Detectors must degrade slowly & gracefully

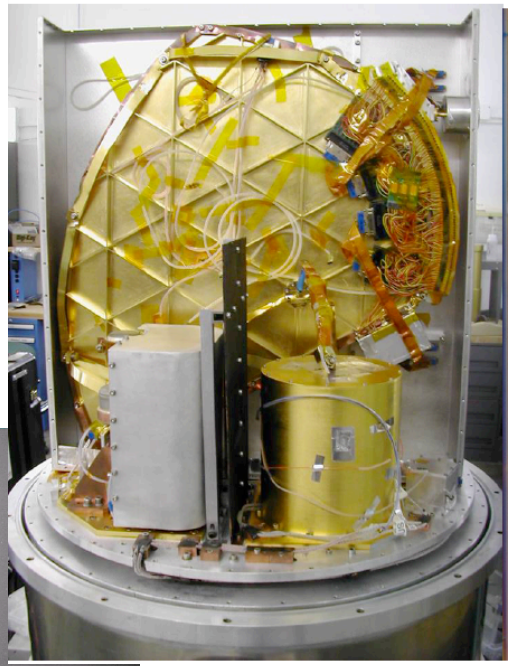

Technologies
FY07
FY08
FY09
FY10
FY11
FY12
FY13
FY14
Cryocooler
ADR
Mechanical Systems
Optical Components
Metrology
Detectors
Subscale Thermal Models
Protoflight Units
Handoff From JWST
5
6
6
Continuous ADR/Cryocooler Demonstration
~10μW at 50 mK
~1 μW at 10 mK
Handoff From Con-X IR&D
5
4
4-stage 50mk
5-stage 10mk
Technology Readiness Level (TRL)
4k Actuator
4k Scanner
4
6
6
6
Trolley
Trolley
Handoff From R&A
4
Beamsplitter
6
Laser
6
6
Bearing Distance, ZPD Path Length Sensor
Handoff From R&A
3
4
5
6
SPIRIT-like Detectors
TES/MKID/STJ Proof of concept
Working 10-19 NEP devices
Multiplexing in formats of 200 elements
Handoff From SCT
4
5
6
Scalable system test
Modeled, scalable ground test
ACT
IM
Instrument
IM = Instrument Module
ACT = Array Collector Telescope
Phase-B 10-11
Inst.PDR 10-14
Inst.CDR 02-14

More with Less

Ground-based, suborbital, and airborne projects provide key opportunities to:

- Test out new technologies, including coolers, detectors, etc.
- Help develop the expertise needed for future space missions
- Do some great science!





Supporting work

Need support for theoretical work and for laboratory astrophysics:

- THz spectroscopy of dust & ice analogs (19; Gerakines)