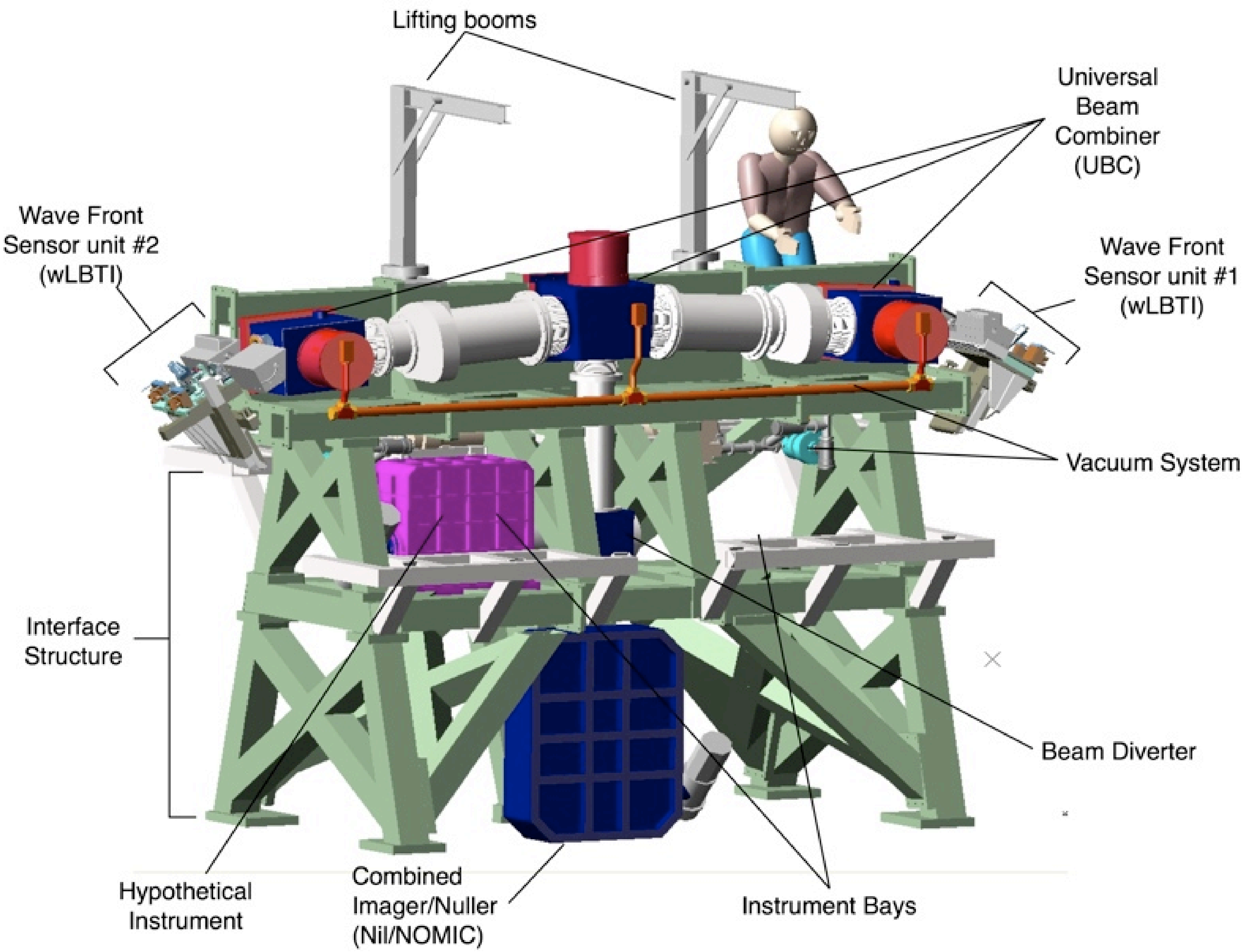
Outline

- Introduction
  - *Science & Science Ops.*
  - *Schedule*
  - *Software overview*
    - *Platforms, OS, Languages*
    - *Architecture*
- Functionalities
  - *Alignment (mechanical at installation)*
  - *Imaging/Nulling*
  - *Standby*
- Special issues

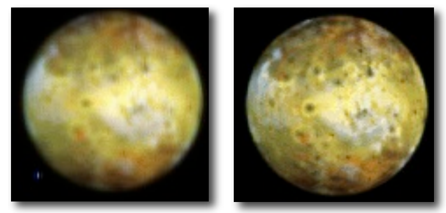
The Instrument



LBTI: Imaging Exo-solar Planetary Systems

With the advent of large telescopes and progress with associated technology, planets around other stars are now detectable, both in principle and in reality. In order to further this search, NASA and The University of Arizona are undertaking the construction of the LBT Interferometer (LBTI). The project will use the Large Binocular Telescope as a testbed to develop nulling and Fizeau interferometry for this purpose. The Large Binocular Telescope will be the world largest and most sensitive telescope on a single mount with an aperture of 23 meters edge-to-edge. Nulling interferometry is a technique which cancels the overwhelming glare from a star by interference of light. This allows the detection of nearby planets or dust disks which would otherwise be obscured by the much brighter star. The technique is being studied in preparation for NASA's Terrestrial Planet Finder Mission. The project is currently in the construction phase. In addition to searching for extrasolar planets the instrument will enable ultra-high resolution, wide-field imaging, allowing the LBT to create images with ten times the resolving power of the Hubble Space Telescope.

Resolution appropriate for I, J, & H bands (simulation by K. Hege)

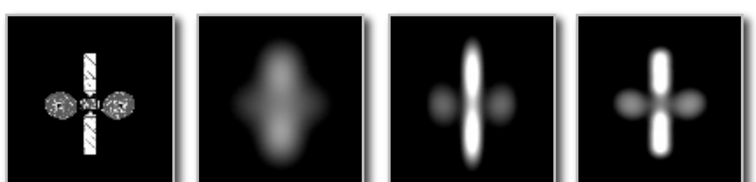


Fizeau imaging snapshot of IO

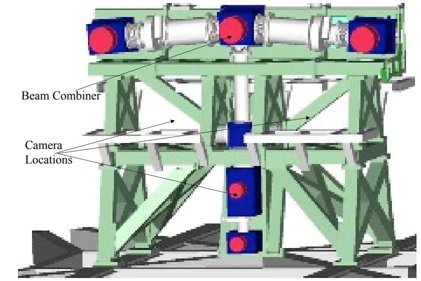
Reconstruction from three images formed at 60° intervals

The LBTI instrument will be constructed and operated by the University of Arizona, Steward Observatory and funded by NASA through the Navigator Program at the Jet Propulsion Laboratory.

Simulated Geosynchronous Satellite Images



21 x 19 m Satellite	6.5 m MMT Diffraction Limit	LBT Diffraction Limit 2 x 8.4 m	GMT Diffraction Limit 7 x 8.4 m



3-D Model of the LBTI

Instrument Highlights

- Observes giant planets, zodiacal dust as markers for presence of terrestrial type planets
- Enables Ultra-high resolution Fizeau Imaging (10x HST) on LBT
- Diffraction Limited Imaging at 1.0µm to 13µm
- 256x256 SiAs BIB Array (8-25µm), 50µm pixel pitch
- 1k x 1k HAWAII Array (3.5-5µm), 18µm pixel pitch
- Instrument commissioning in early 2008
- 100µJ Photometric Sensitivity @13µm
- 40x60 arc-second FOV in Imaging mode

Telescope Highlights

- Two 8.4m, f/1.1 Borosilicate Primary Mirrors
- 22.8 meter x8.4 meter effective aperture
- Tertiary Flats (2), 50x64cm, 4 degrees of freedom
- Adaptive Secondaries (2)

Adaptive Optics Highlights

- 911mm diameter, 1.6mm thick
- 672 Voice coil actuators
- 336 DSPs (60 GigaMAC computational power)
- 2.6kW Power consumption
- Glycol/H_2O cooled to within 1°C of air temperature
- 1KHz Closed loop operations

Operations Overview

- Run as PI instrument
  - *Always instrument scientist*
  - *Limited automation*
- *PI Science Program (NIREST)*
  - *Small team of observers*
- *NASA GO (Guest Observing)*
  - *Queued Observing program executed by Instrument Scientist*

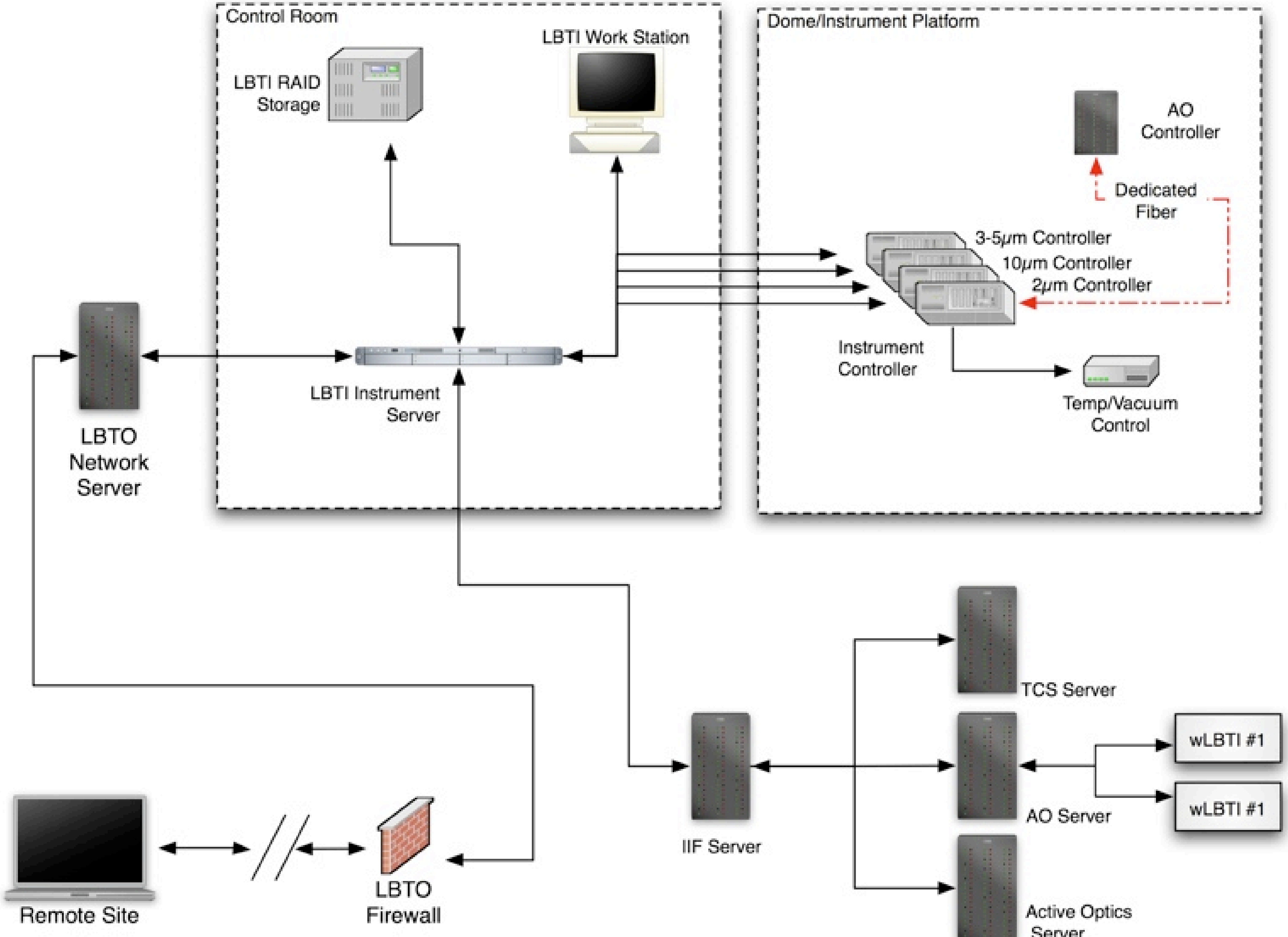
Schedule

- 2006
  - *MMT Prototype testing*
    - *Software, Hardware, Techniques, Procedures*
  - *UBC Testing in the lab - Present - mid ’07*
    - *Internal software*
- 2007
  - *Fabrication of Nulling imager*
  - *IIF Software interface testing*
- 2008
  - *Delivery to Mt Graham in Jan ’08*
  - *Commissioning*
- 2009 - 2017
  - *Science Ops*

Software Overview

- Specifics
  - *Industrial PC Based platforms*
    - *Primarily Linux OS*
    - *Some Windows black boxes*
  - *Language*
    - *C with mix of C++*
    - *TCL/TK, Perl*
    - *IDL (Limited use)*

LBTI System Schematic



Modes

- Initial Alignment
- Fizeau Imaging
- Nulling
- Standby

(Fizeau Imaging and Nulling: considered the same for this presentation)

Initial Alignment

- Completed during the installation of LBTI on telescope
- Will require manual control of Active optics and other facility functions
  - *Expect to accomplish this with engineering staff and TO/AOO support*

Observing Mode

- This flow diagram describes all modes of observing
- Let's take a closer look at the 2 groups

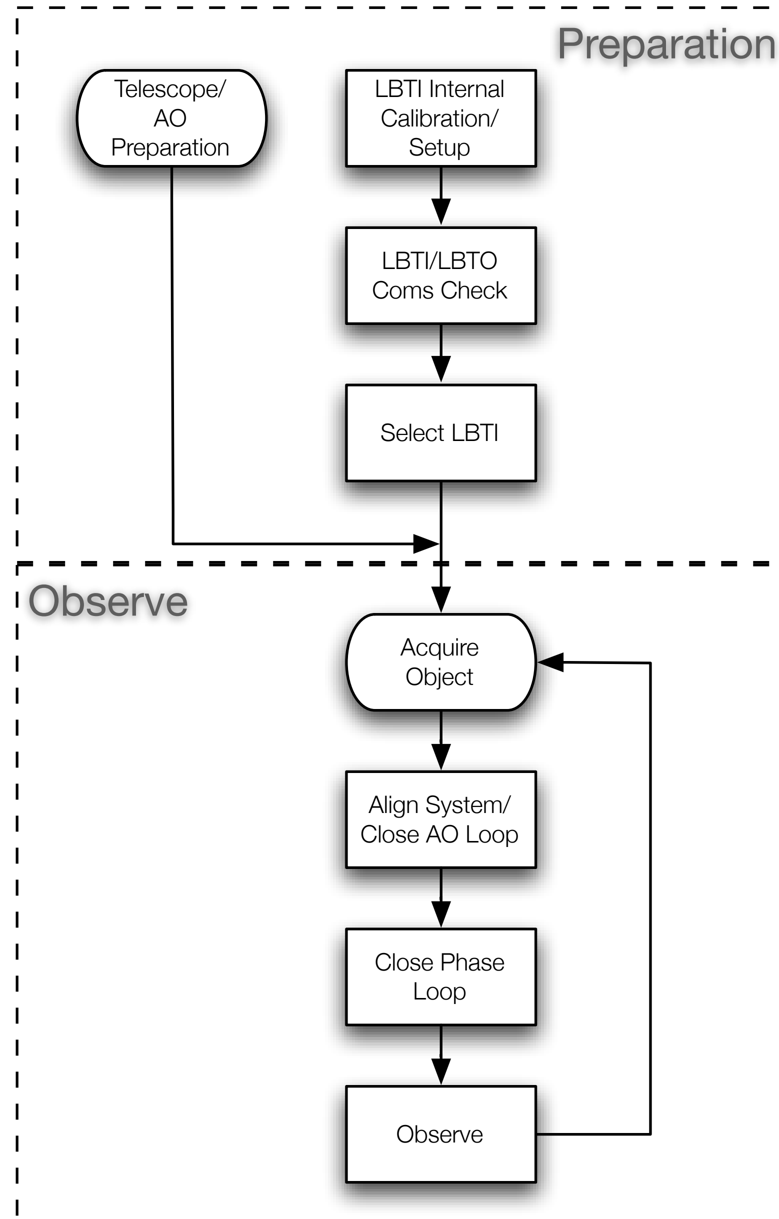
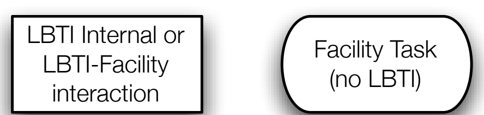


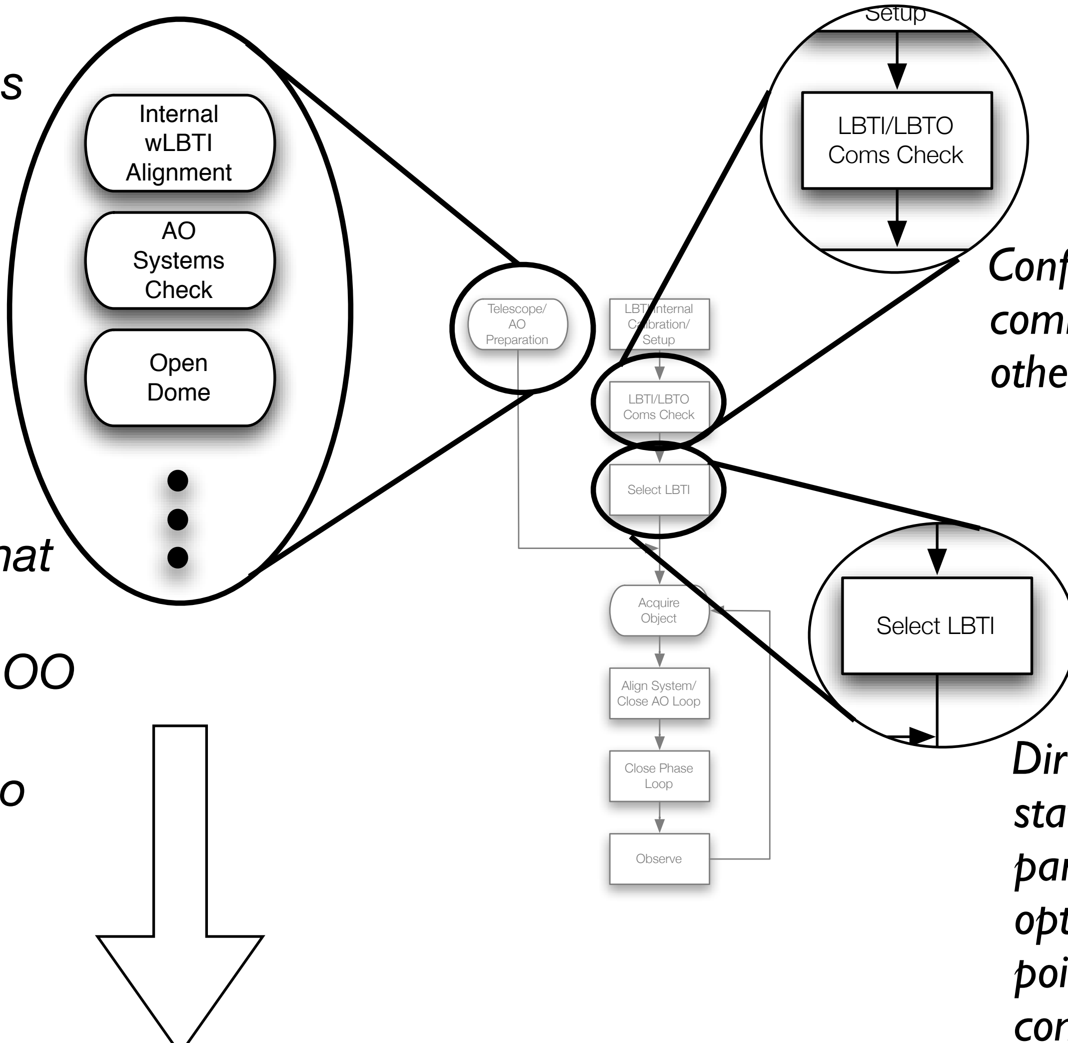
Diagram Key



Preparation

Observatory activities and tasks that are transparent to LBTI

The Instrument will require verification that tasks have been accomplished (TO/AOO interaction or status flags) to continue into observing phase



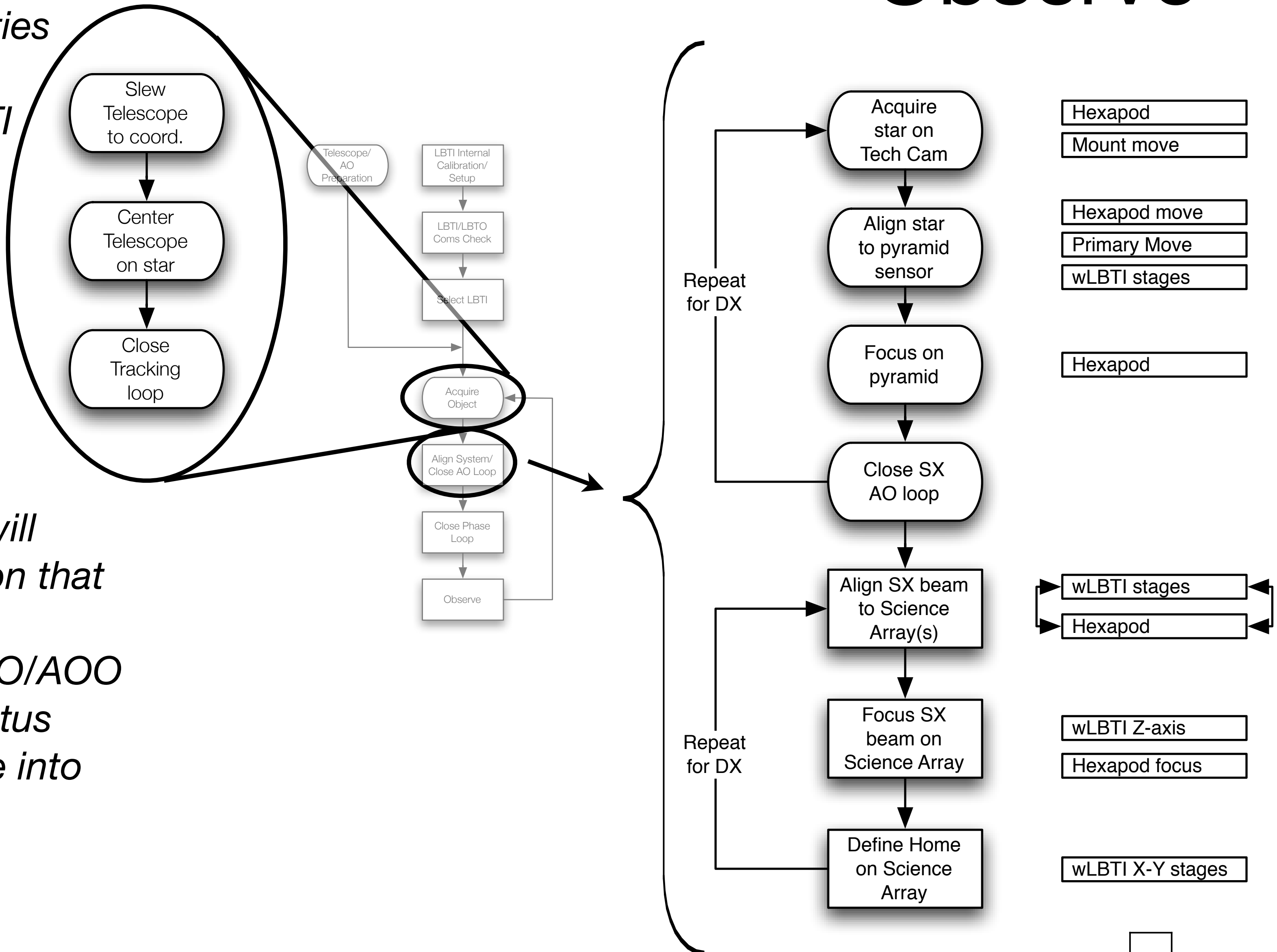
Confirmation of bi-directional communications with IIF + others subsystems

Directs the beam to central station, loads custom parameters and presets to optimize observing (e.g. pointing model). May be a command from LBTI controller.

Requirement:
Status related to “state of the observatory” available to instrument controller

Observe

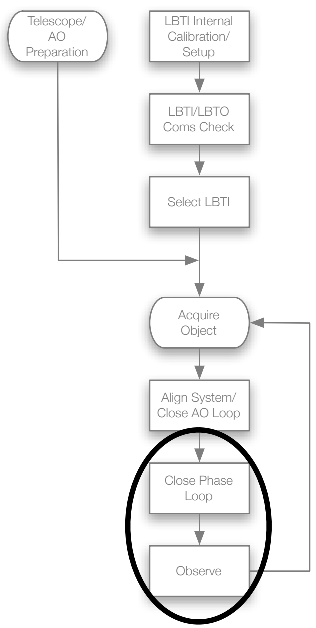
Observatory activities and tasks that are transparent to LBTI



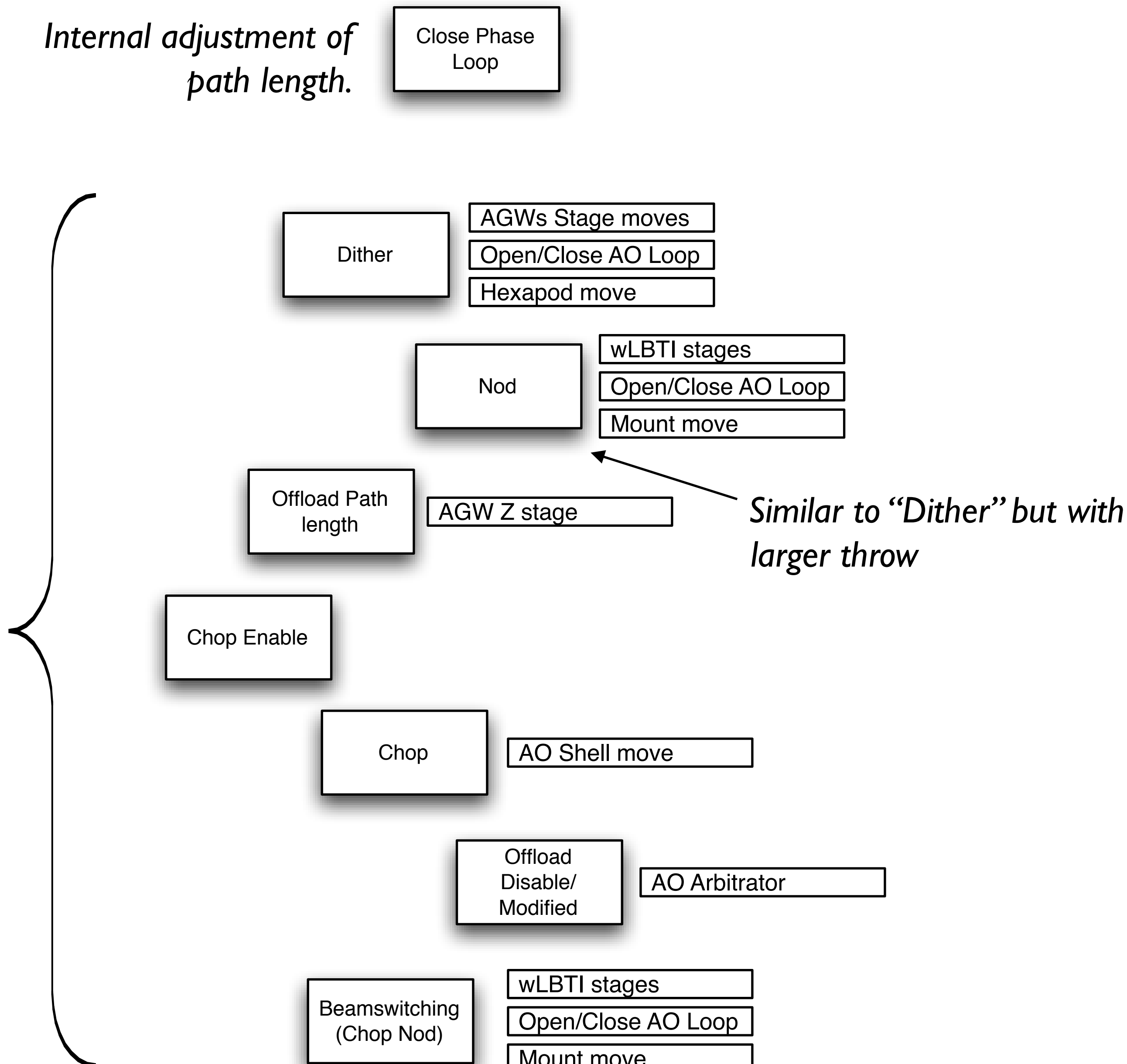
The Instrument will require verification that tasks have been accomplished (TO/AOO interaction or status flags) to continue into observing phase

Requirement:
Instrument control of hexapod, AGW unit stages, focus control of shell

Observe (Phase Control)

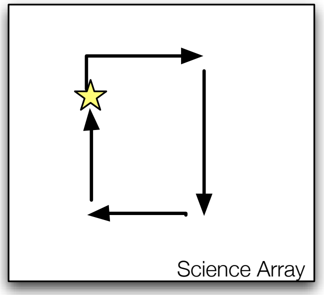


Science Observing Actions (non-sequential)

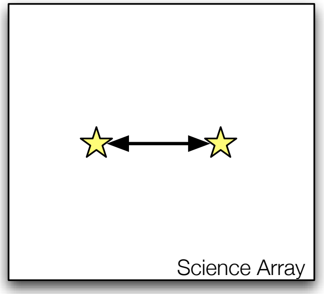


* Master = SX
Slave = DX

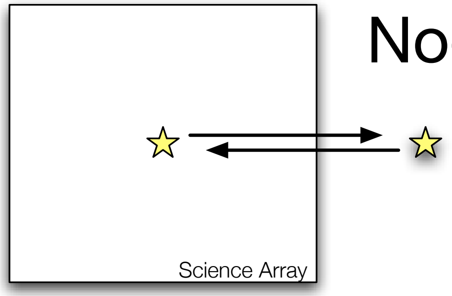
Observing Tasks



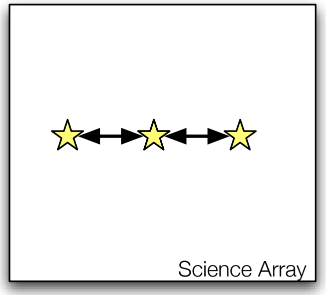
Dither



Chop

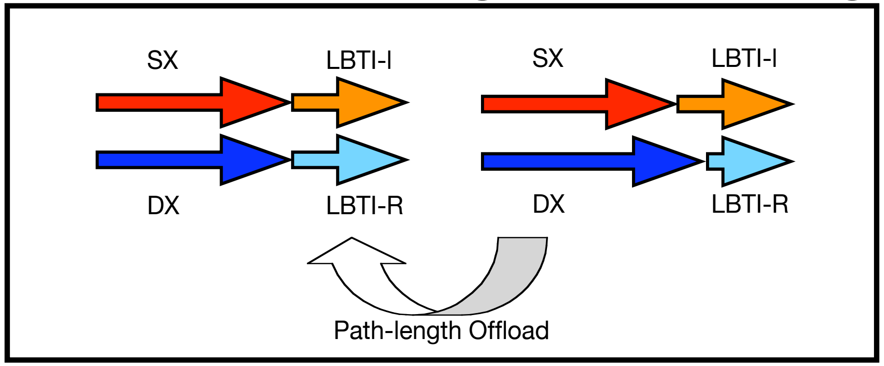


Nod



Beam switching

Path-length Offloading



Standby

- Monitoring
    - *Request some reflected memory to store key parameters so that Obs. Personnel can read the "State of the Instrument" to determine if any action needs to be taken*
    - *Could have a monitor window on any workstation*
- Maintaining readiness
    - *Could (should?) have lockout mode that would protect systems from inadvertently being turned on/off*
- Suggest that Observatory generate policies for this type of mode

Timing: N/A = Don't care
Slow = 10s<t<1s
Medium = 1s < t < 0.1s
Fast = 0.1s <t < 0.001s

LBTI Tasks

When	Item	Task	Timing Req.	Response	Systems Involved	Comments
Nightly Setup	1	Select LBTI	Slow	ACK, Flag	Active optics (tertiary), wLBTI, Other?	Sets the LBTI as the observing instrument directing the beam into the central instrument position, adjusting other parameters that may be tailored for LBTI (e.g. pointing model)
	2	Collimate	N/A	N/A	AOS, AAOS	Facility "canned" routine
	3	Stealth Mode	Slow	Facility data	Facility, TO, AOO	Shut down noisy systems (e.g. blowers, chillers) to enable high sensitivity nulling. Can be accomplished initially via TO & AO Operator.
	4	LBTI Com Check	Slow	ACK	IIF, AAOS, TCS, wLBTI	Checks for com to targeted subsystems
	5	Align Science Array	Slow	N/A	Hexapod, wLBTI stages	Co-align WFSs and science arrays. May require access to WFS images.
	6	Science Array Focus	Slow	Completed request	AAOS, Hexapod	Fine tune focus via wLBTI z-axis stage (i.e. move WFS camera
Observing Ops	7	Nod	Medium	ACK, Complete	TCS, AAOS	Move the star off Science array FOV. Similar to Dither but for larger movements. Requires opening and closing AO loop
	8	Chop	Fast	N/A	AAOS, wLBTI	Trigger synchronized chop of DX & SX secondaries
	9	Chop Enable/Disable	Slow	Ready	AAOS, wLBTI	Perform setup for chopping
	10	Dither	Medium		wLBTI stages	Scan object across Science array while maintaining AO loop closure
	11	Disable/Modify Offload	N/A	ACK, Flag	AO Arbitrator?	Disable optical offloading maintaining static mirror configuration. We would want to have this with adjustable parameters to specify which optics to enable or disable. Directed to AO Arbitrator?
	12	Offload Path length	Slow	ACK	AAOS, Hexapod	Correct the path-length difference between SX & DX sides. This occurs when LBTI path-length correction bandwidth reaches/ nears limits.
	13	Beam switching	Medium	ACK	AAOS	Switch between the chopped stellar images within the science array FOV

AAOS = Adaptive Optics Sys.
AOS = Active Optics Sys
TCS = Telescope Control Sys
wLBTI = LBTI WaveFront Sensors (== AGW units)

Telemetry Data

- Vibration
  - *100 Hz or better*
- Standard Items
  - *Time, pointing, weather, tracking errors, etc...*
  - *State of the observatory*
    - *e.g. Dome open, cooling fan speeds, stealth fans*
- Tech Viewing Camera and WFS images
  - *WFS for alignment purposes (not continuous)*
  - *Tech Viewing Camera continuously*
  - *Sub-Full frame rate (~2-15Hz)*