IAS Command Line Interface

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Version of 7/19/95 D. Blanco
Changes since draft release:
SET and ADJUST are used instead of GOTO and OFFSET. Stage command syntax has been altered to more closely conform the WIYN CLI syntax. MODE command has been introduced to change coordinates. Units for focus stages have been changed to microns.

CONTENTS:

Appendices

1. Introduction

This document describes the command line interface for control of the instrument adapter system (IAS). The IAS is a general guider and science instrument interface for the WIYN telescope. The IAS is described in WODC 01-18, WODC 01-19 and in the IAS critical design review book (also known as the Book of the IAS).

The IAS command line interface (CLI) includes a set of commands that let the user initiate motions and set parameters inside the IAS. These commands initiate processes which directly control the functions of the IAS, perform coordinate transforms, units conversion, housekeeping and related functions, and update a telemetry display page. The IAS CLI is a direct user interface and serves as a bridge between a Graphical User Interface (GUI) and the IAS.

Commands to the IAS contain several words delimited by spaces. These are preceded by a 'zero-th' word 'IAS' to identify the following words as a command addresses to the IAS process. For simplicity this zero-th word has been omitted in the command descriptions in this document.

On receiving a command the process checks to see if the command is valid. Invalid commands trigger an error message; valid commands are identified as either primitive, high level, or top level. Primitive commands need no more than a conversion from real units (mm, degrees, seconds, etc.) into the raw units used by the IAS onboard processor (motor steps, steps per second, etc). High level commands typically require further processing such as coordinate conversions, calculations and housekeeping. Top level commands initiate a sequence of lower level commands repeated every few seconds. These commands dynamic processes which automatically correct for atmospheric dispersion and compensate for instrument flexure.

On power-up the IAS controller has no knowledge of the status and position of many of its components. Positions are established by driving the stages, slides or wheels to their 'home' positions where fiducial switches establish a start position.

The WIYN IAS page displays the status and position of all IAS components. The page is updated each time a CLI command is executed. Reverse video is used in three ways: first, if an error condition is detected the component status will be displayed in reverse video. Second, when components such as the dark slide block light to the science instrument the component name is shown in reverse video. Finally, when a command is issued to move a component, the position is displayed in reverse video to denote that it is not in it commanded position.

2. Coordinates

The IAS process uses two Cartesian coordinate reference frames; the first, called BOX is fixed to the IAS box. Ultimately all stage positions refer to this coordinate frame, however, the positions in the BOX coordinate frame are not displayed per se. Instead, we define a Cartesian frame BASE with axes parallel to the BOX axes but with its origin located at a point Xs,Ys in the BOX coordinate frame. Normally Xs and Ys are zero (the default condition) and the BASE frame coincides with the BOX frame. The BASE frame is moveable and can be set to coincide with the center of the instrument.

By using the MODE command, the user can elect to convert the BASE and BOX coordinate frames into any of three celestial coordinates. Commands to position the IAS probe cameras are entered in the selected coordinate mode. Azimuth and elevation coordinates are allowed only for offsets, not for absolute position commands.

Most high level commands from the CLI refer to the BASE coordinate frame, and the WIYN telemetry page displays the stage positions in BASE coordinates.

2.1 BOX and BASE coordinate frames

BOX coordinates refer to a right-handed Cartesian frame with origin at the center of the IAS box at the instrument mounting surface (127 mm above the focal plane). When the box is mounted on the WIYN Nasmyth instrument rotator (NIR) and oriented so that its Y axis is vertical, the instrument patch panel is in the lower right, the Z axis coincides with the optical axis of the telescope and is positive in the direction of travel of the light beam, and the X axis is positive to the right. The origin of the BOX coordinate frame lies on the NIR axis.

By definition the boresight of the telescope passes through the origin of the BOX coordinate frame. In normal operation the NIR is oriented so that the positive Y axis points towards celestial north. The effect of an NIR offset is to rotate the Y axis away from celestial north. When the NIR is not tracking, or when the NIR is in 'mount track' mode (tracking the elevation axis), the rotator offset angle will be constantly changing.

The BOX Z axis has little meaning for the control commands; instead we define an 'F' focus axis. F is parallel to the optical axis with its origin at the paraxial focus of the telescope. F is positive towards the secondary mirror. Moving a focus stage in the positive F direction moves the camera 'up focus' in image space.

2.2 Celestial coordinates

Coordinates of the guide probes can be displayed in any of three celestial coordinate systems, equatorial, ecliptic, or galactic. The IAS celestial coordinates are projected onto a plane tangent to the celestial sphere at the RA, DEC position of the telescope boresight. The procedure for mapping celestial coordinates onto BASE coordinates is given in appendix A.

3. IAS axes

The following list gives the axis numbers, device names, component names, and component type for all IAS axes. The cpu inside the IAS box uses axis numbers and opcodes to identify axes and commands. The CLI command structure uses device and component names to identify axes.

AXIS NO.	DEVICE	COMPONENT	TYPE
1	DARK	SLIDE	SLIDE
2	ADC	SLIDE	SLIDE
3	ADC	A-ROTATOR	STAGE
4	ADC	B_ROTATOR	STAGE
5	FEED	SLIDE	SLIDE
6	GPROBE	X	STAGE
7	GPROBE	Y	STAGE
8	GPROBE	F	STAGE
9	GPROBE	FILTER	WHEEL
10	GPROBE	COLOR	WHEEL
11	FPROBE	X	STAGE
12	FPROBE	Y	STAGE
13	FPROBE	F	STAGE
14	FPROBE	FILTER	WHEEL
15	FPROBE	COLOR	WHEEL
16	FPROBE	PUPIL	WHEEL
17	CIA	FILTER	WHEEL
18	WFSCAM	Y	STAGE
19	WFSCAM	F	STAGE
20	WFSCAM	FILTER	WHEEL
21	SPARE	SLIDE	SLIDE
22	SPARE	A_STAGE	STAGE
23	SPARE	B_STAGE	STAGE

Commands to all axes use the device name ALL to denote all axes. The only exception is emergency stop (ESTOP) which stops all axis motion.

NOTE: In addition to the 'IAS ESTOP' command the IAS is hard-wired into the emergency stop switch system. When an emergency stop switch is depressed all power to the IAS is cut. Recovery from an emergency stop switch involves re-initializing all IAS axes.

3.1 Units

CLI commands are in real units appropriate to the axes. These must be translated into units used in the on-board IAS cpu opcodes. Opcode commands are in units of steps, steps per seconds for speed, steps per second squared for acceleration, or position numbers for slides and filter wheels.

The conversions are:

ADC	a-rotator	10 steps/degree
ADC	b_rotator	10 steps/degree
GPROBE	X	100 steps/mm
GPROBE	F	12.7 microns /step
FPROBE	X	100 steps/mm
FPROBE	Y	100 steps/mm
FPROBE	F	12.7 microns /step
WFSCAM	X	100 steps/mm
WFSCAM	F	100 steps/mm
Spare	a_stage	TBD
Spare	b_stage	TBD

3.2 Ranges and home positions

The process maintains a record of stage travel limits for the linear stage devices (FPROBE, GPROBE AND WFSCAM). These will be hard coded. A second hard coded limit will define the outside radius of the useable image field, Ro. In addition there will be a user set-able radius Ri to describe an inner "forbidden zone" where a positioned probe would vignette central beam used by the science instrument.

Neglecting the forbidden zone, the nominal range of the IAS stages (in BOX coordinates) are:

		FPROBE	GPROBE	WFSCAM	Units
X	min	-100	-100	--	mm
	max	+100	+100	--	mm
Y	min	0	-100	-100	mm
	max	+100	0	+100	mm
F	min	-25,000	-25,000	-50,000	microns
	max	+25,000	+25,000	+50,000	microns
Home	X	-100	+100	--	mm
	Y	+100	-100	+100	mm
	F	0	0	0	microns

Note: the WFScam can only move along the BOX Y axis. In some documents this has been labelled the 'WFScam X axis'.

Nominal range values will be updated with measured values during IAS commissioning.

4. CLI primitive commands

CLI primitive command syntax follows established guidelines for compatibility with the rest of the WIYN CLI. The syntax is arranged in a semi-English structure. For convenience, it is only necessary to type enough of the first letters of a word to uniquely define that word (usually three), though the full command word is always accepted and should be used in code for clarity. For example, the command "IAS FPROBE FILTER BLUE" can be entered as "IAS FPR FIL BLU".

NOTE: Commands to the IAS process are ALWAYS preceded by a zero-th word 'IAS' to identify them as belonging to the IAS command set. For clarity this zero-th word is generally omitted in this document.

4.1 Primitive command syntax

Primitive commands to individual axes are arranged in a syntax of the form:

DEVICE COMPONENT (ATTRIBUTE) ACTION (VALUE)

COMPONENTS are individual axes grouped together to form a DEVICE; for example, the focus probe (FPROBE) consists of the components X (X stage, Y (Y stage, F (focus stage), FILTER (neutral density filter wheel, COLOR (color filter wheel), and PUPIL (pupil optics wheel).

The optional ATTRIBUTE distinguishes among several user settable parameters.

The optional word VALUE denotes position in units appropriate to the component.

4.2 Primitive command set

IAS COMMAND	OPCODE	VALID AXES	ACTION
ALL RESET	0	NONE	resets all parameters to default values
ALL HOME	1	NONE	moves all axes to their home positions
ESTOP	2	NONE	emergency stop
ALL STATUS	3	NONE	requests status of all axes
RESET	10	ALL	resets axis parameters
HOME	11	ALL	moves axis to home
STOP	12	ALL	executes a controlled stop
STATUS	13	ALL	requests axis status
POSITION SET (VAL)	20	STAGES	go to absolute position
POSITION ADJUST (VAL)	21	STAGES	move relative value
REGISTER SET (VAL)	22	STAGES	changes axis position register to VAL
SPEED SET (VAL)	23	STAGES	sets maximum stage speed to VAL

ACCELERATION SET (VAL)	24	STAGES	sets maximum stage acceleration to VAL
QUERY	25	STAGES	requests current stage position and velocity
POSITION SET (VAL)	30	WHEELS	moves stage to position number VAL
QUERY	31	WHEELS	requests current wheel position
IN/OUT	40	SLIDES	moves
STATUS	41	SLIDES	requests stage status
ON/OFF	50	NONE	turns lamps on or off
STATUS	51	NONE	requests status of ---
READ	60	NONE	requests of 8 A to D channels
ON/OFF	61	NONE	turns 5V power on or off (used by LVDT's)
STATUS	62	NONE	requests status of

5. High level commands

High level commands issue one or more primitive commands based on calculations carried out in the process code. This includes compensation for stage non-orthogonality, determination of focus stage position to follow image field curvature, compensation for image field distortion, and conversion from celestial to BASE coordinates. The process retains stage limits (in the BOX coordinate frame) and determines if the commanded stage target position is within the limits. If not, the process returns an error code.

5.1 Filter commands

5.1.1 Filter command syntax

Filter commands follow the syntax:

(DEVICE) (COMPONENT) (POSITION)

Filter POSITION is in english (RED, BLUE, ND, DARK). The direction of motion is determined by the on-board IAS processor to preclude moving through a filter position that might over-illuminate the camera or instrument.

5.1.2 Filter command list

BLUE
Valid axes: FPROBE COLOR, GPROBE COLOR
Moves color filter wheel to blue filter position.

CLEAR
Valid axes: CIA FILTER, FPROBE FILTER, FPROBE COLOR, GPROBE FILTER, GPROBE COLOR, WFSCAM FILTER
Moves filter wheel to clear window position.

DARK
Valid axes: FPROBE FILTER, GPROBE FILTER
Moves color filter wheel to blue filter position.

INSIDE
Valid axes: FPROBE PUPIL
Moves pupil wheel to inside of focus (INSIDE) position.

ND
Valid axes: FPROBE FILTER, GPROBE FILTER
Moves filter wheel to 0.5 neutral density filter position.

OUTSIDE
Valid axes: FPROBE PUPIL
Moves pupil wheel to out of focus (OUTSIDE) filter position.

POS2, POS3, POS4
Valid axes: CIA FILTER, WFSCAM FILTER
Moves filter wheel to position 2,3,4.

RED
Valid axes: FPROBE COLOR, GPROBE COLOR
Moves color filter wheel to red filter position.

5.1.3 Fprobe filter (neutral density filters)

FPROBE FILTER (DARK,ND,CLEAR)

This is a three position filter wheel with a clear window, a 0.5 ND filter, and an opaque filter (DARK) which serves as a probe camera shutter. The home position is dark.

5.1.4 Fprobe color wheel (color filters)

FPROBE COLOR (CLEAR,RED,BLUE)

This is a three position color filter wheel with a clear window, a red filter, and a blue filter. The home position is clear.

5.1.5 Fprobe pupil (pupil optics wheel)

FPROBE PUPIL (CLEAR,SPLIT,OUTSIDE,INSIDE)

This is a four position wheel located at a pupil plane in front of the focus probe camera. The four positions are CLEAR, SPLIT (splits the camera image in two), OUTSIDE for outside of focus (moves a weak positive lens into the beam), and INSIDE for inside of focus (moves a weak negative lens into the beam). These optics are used for focus sensing and for the AUTOFOCUS process (described in WODC TBD). The home position is CLEAR.

5.1.6 Gprobe filter (neutral density filter wheel)

GPROBE FILTER (DARK,ND,CLEAR)

This filter is similar to the fprobe filter wheel.

5.1.7 Gprobe color (color filter wheel)

GPROBE COLOR (CLEAR,RED,BLUE)

This filter is similar to the fprobe color wheel.

5.1.8 WFScam filter wheel

WFSCAM FILTER (CLEAR,RED,BLUE,TBD)

This is a four position filter wheel located in front of the wavefront sensing camera. The filters are TBD.

The home position is TBD. The wheel is commanded to uniquely encoded positions 1 through 4. Direction of travel is TBD.

5.1.9 CIA filter wheel

CIA FILTER (CLEAR, POS2, POS3, POS4)

This is a four position filter wheel located at the outlet of the comparison integrating sphere. The filters are TBD.

The home position is CLEAR. The wheel is commanded to uniquely encoded positions 1 through 4.

5.2 Coordinate system selection

The user can select between various coordinate systems using the MODE, EPOCH and EQUINOX commands. All position commands relayed to the IAS and telemetry from the IAS shown on the WIYN page are displayed in the coordinate frame selected.

NOTE: The EQUINOX and EPOCH should always be the same used for positioning the telescope.

5.2.1 MODE command

MODE (BASE, ALT-AZ, ECLIPTIC, EQUATORIAL, GALACTIC)

Allows selection between the BASE coordinate system (in mm) and three celestial coordinates systems. When this command is executed the WIYN page is updated to display all positions in the selected coordinate mode. All subsequent position commands are converted from the selected coordinate mode to the BOX coordinate frame for execution. See appendix A for conversions.

ALT-AZ coordinates are included primarily to allow incremental moves in the altitude and azimuth directions.

5.3 X-Y stages

The GPROBE and FPROBE cameras are mounted on X-Y stages that can be positioned around the image field. Commands to move these stage can be either absolute (POSITION SET) or incremental (POSITION ADJUST), with position given in the current coordinate mode.

An ADJUST command followed by a SET command moves the device to the absolute position given in the SET command, not the absolute position plus the last ADJUST. Retained offsets for an individual stage are done with the command REGISTER SET. The command ORIGIN (section 5.3.5) can be used to introduce a global translation offset for all stages.

The WFScam is mounted on a single axis stage that can be moved across the field. Commands for this stage are limited to a single axis R which bisects the image plane along the BOX Y axis. R is in mm (BASE coordinates) or degrees, minutes and seconds (celestial coordinates).

The guide and focus probes can be moved to positions which are outside of the image field. When a commanded target is outside of the image field the IAS process returns a warning but executes the command.

The user can also set an inner limit defining the part of the beam used by the instrument (see the AVOID command, section 5.2.4). If the target is within this "Forbidden zone" the process returns a warning message and requests confirmation before executing the move.

If the user has enabled focus tracking, then the device focus stage will be offset by the correct amount to follow the curvature of the focal plane keeping the probe or wavefront sensing camera in focus.

5.3.1 X-Y Stage command syntax

The command syntax for X-Y stages is:

    DEVICE (ATTRIBUTE) ACTION (VALUE1, (VALUE2))

DEVICES:	FPROBE, GPROBE, WFSCAM
ATTRIBUTE:	POSITION, REGISTER
ACTIONS:	SET, ADJUST
VALUE:	position or distance in current coordinate

mode

EXAMPLES: GPROBE POSITION SET (V1,V2)
moves the guide probe to V1, V2

FPROBE POSITION ADJUST (V1,V2)
moves the focus probe a distance V1, V2 from the present position

GPROBE REGISTER SET (V1,V2)
sets the guide probe registers to the values V1,V2

5.3.2 X-Y Stage command set

Valid linear stage commands are presented and briefly explained in the following list. More complex commands are discussed in subsequent sections.

AVOID (R,A,B)
Valid devices: FPROBE, GPROBE, ALL
Allows user to define a forbidden zone of radius R centered at A,B. For BASE coordinates R, A, and B are in mm. For celestial coordinates R, A, and B are in d,m,s. See section 5.3.4.

INITIATE
Valid devices: FPROBE, GPROBE, WFSCAM, ALL
Moves the device stages to their home positions and sets each stage position counter to a default home position location value.

PARK
Valid devices: ADC, FPROBE, GPROBE, WFSCAM, ALL
Moves the device stages to the home position, but does not reset the position counter.

POSITION ADJUST (A,B)
Valid devices: FPROBE, GPROBE, WFSCAM
Moves the stage incremental distances (A,B) in the current reference frame. See section 5.3.3.

POSITION SET (A,B)
Valid devices: ADC, FPROBE, GPROBE, WFSCAM
Moves the stage to absolute position A,B in the current reference frame. See section 5.3.3.

REGISTER ADJUST (A,B)
Valid devices: ADC, FPROBE, GPROBE, WFSCAM
Changes the position register by the given values in the current reference frame.

REGISTER SET (A,B)

Valid devices: ADC, FPROBE, GPROBE, WFSCAM
Changes the position register to the given values in the current reference frame.

STOP
Valid axes: ADC, FPROBE, GPROBE, WFSCAM, ALL
Executes a controlled stop of all stages in the device.

TRACK ON or OFF
Valid axes: FPROBE F, GPROBE F, WFSCAM F, ALL
Turns on focus tracking for the FPROBE, GPROBE or WFSCAM focus stages. See section 5.4.

5.3.3 X-Y stage SET and ADJUST commands

The commands SET and OFFSET require special processing to perform coordinate transforms. These commands are followed by position or distance values in the current coordinate mode.

Valid coordinate modes:

BASE	Use the BASE coordinate frame in mm.
ECLIPTIC	Use ecliptic coordinates.
EQUATORIAL	Use the equatorial coordinates.
GALACTIC	Use Galactic coordinates
AZEL	Use an Azimuth-Elevation coordinate frame in degrees.

On receiving a SET or ADJUST command the IAS process performs the following steps:

1) Convert VALUE1, VALUE2 from current coordinates to an X,Y TARGET in BOX coordinates in mm (see appendix A).

2) Check if the TARGET is inside the range of stage travel. If not, return error code "TARGET OUT OF RANGE". Device does not move.

3) Check if TARGET is inside the useable image field. If not, display warning "TARGET OUT OF FIELD", and proceed.

4) Check whether TARGET is within the forbidden zone. If it is, return warning "TARGET IN FORBIDDEN ZONE" and proceed.

5) Check if FOCUS TRACK in ON. If so, determine the focus offset for the device being commanded based on the change in radial distance from the IAS axis.

7) Convert from BOX coordinates (mm) to stage coordinates (steps). This includes correction for stage non-orthogonality (appendix B).

8) Issue X,Y and F stage primitive commands.

5.2.4 The AVOID command and the forbidden zone

(DEVICE) AVOID (R,A,B)

Valid devices: FPROBE, GPROBE, ALL (both)

Allows the user to define a circular forbidden zone of radius R with its center at point A,B in the current coordinate frame. When set, commanding a probe to a position inside the forbidden zone will result in a warning "TARGET IS IN THE FORBIDDEN ZONE'. Despite this warning the command is executed. The display page paints the device name in reverse video to denote that the probe is blocking light to the science instrument.

Entering an R of 0 (zero) clears the avoidance condition.

5.2.5 The ORIGIN command

ORIGIN (Xs,Ys)

No device names are used with this command.
Effected devices: FPROBE, GPROBE, WFSCAM

The ORIGIN command sets the origin of the BASE coordinate frame to point Xs,Ys in the BOX coordinate frame and initiates the following high level commands:

```
MODE BASE
ADJUST FPROBE Xs,Ys
ADJUST GPROBE Xs,Ys
ADJUST WFSCAM Ys
```

Since the commands initiate motion, the IAS display page will be updated to show the stage positions in the new BASE coordinate frame. Since the BASE frame has been translated to point Xs,Ys, the net result is that the absolute positions in both the BASE and SKY coordinates will be the same after executing the command as they were before. However, the probes have moved to a new position. This command is used to center the guider axes onto the center of the science instrument.

NOTE: The ORIGIN command is intended to correct for SMALL offsets between instrument center and the IAS BOX center on the order of one or two mm. Large changes in the base origin can result in stages being commanded to positions outside of their ranges triggering error codes.

5.4 Focus stages - the TRACK command

(DEVICE) TRACK ON and TRACK OFF

Valid devices: FPROBE F, GPROBE F and WFSCAM F, or ALL (all three)

When TRACK is ON the device focus stage will be offset by the correct amount to follow the curvature of the focal plane keeping the probe or wavefront sensing camera in focus. An algorithm for determining the focus offset is given in appendix D.

5.5 Rotary stages

The ADC device uses two rotary stages for each of two lens-prism (or "lensm") pairs. These act as a field corrector and flattener, and when counter-rotated, can introduce a controllable dispersion to compensate for the dispersion introduces by the atmosphere.

5.5.1 Rotary stage SET and ADJUST commands

```
ADC POSITION ADJUST (BASE,DIFF) and
ADC POSiTION SET (BASE,DIFF)
```

High level commands to track the ADC consist of a direction angle BASE, and a difference angle DIFF. The base angle defines the direction of dispersion compensation, usually pointed towards topocentric zenith. The difference angle controls the amount of dispersion. On the command SET the individual stages are driven to absolute angles A and B determined by:

```
A = BASE + DIFF
B = BASE - DIFF
```

An ADJUST command moves the stages from the present absolute positions A,B to new absolute positions A' and B':

```
A' = A + BASE + DIFF
B' = B + BASE - DIFF
```

6. Top level commands

Top level commands initiate sequences of high level and primitive commands which are repeated every few seconds. These are used to automatically compensate for atmospheric dispersion and for instrument flexure.

6.1 Atmospheric dispersion compensation - ADC TRACK command

```
ADC TRACK ON (P,T) , ADC TRACK OFF
```

The command ADC TRACK ON enables automatic atmospheric dispersion compensation. This involves tracking the ADC's two rotation stages to positions determined from the zenith distance, the direction towards zenith in the IAS reference frame, and on an atmospheric model. Parameters used in the atmospheric model include the pressure P(mm Hg) and temperature T(C). If these are not given, the process will substitute default values for a standard atmosphere at the altitude of the site:

P = 592.7
T = 1.5

The algorithm in appendix A.7 returns the direction to topocentric zenith and zenith angle based on the line of site coordinates and the rotator offset angle.

The algorithm in appendix C returns the angle DIFF using an atmospheric dispersion model. In addition to the angle DIFF, the algorithm returns the magnitude of dispersion compensation DISP in arcseconds which is displayed in the WIYN page.

When initiated the process recalculates and updates the ADC stage positions every 10 seconds.

6.2 Instrument flexure compensation - the FLEXURE command

The IAS box structure is designed to provide a rigid mounting surface for the science instrument, however, despite our best efforts it is possible to develop flexure between the science instrument and IAS guide cameras. Flexure compensation involves mapping the position of the image on the instrument as a function of the rotator-to-vertical angle. This map is entered into a look-up-table (LUT). When flexure compensation is enabled the origin of the IAS base frame is dynamically updated so that it remains fixed to the instrument.

```
FLEXURE ON (n,A1,X1,Y1, .... An,Xn,Yn)
FLEXURE OFF
```

No device names are used with this command
Effected devices: FPROBE, GPROBE, WFSCAM

n	is the number of measured image positions (3 minimum, 60 maximum)
Ai	is the i-th rotator-to-vertical angle
Xi,Yi	is the measured image position at Ai measured in the BOX coordinate frame.

If none of the values in parentheses are given, the model defaults to the last values entered. This allows the operator to load the flexure terms once and then easily turn flexure compensation on or off.

The process creates an n by 3 LUT matrix with the measured values Ai,Xi,Yi. When FLEXURE is ON the process interpolates the LUT to determine Xs,Ys values for the current rotator angle. The process then issues the command:

```
ORIGIN -Xs,-Ys
```

This sequence is repeated every 5 seconds.

6.2.1 Mapping IAS-to-instrument flexure

For an imaging instrument flexure mapping is straightforward.

To start, we will need to determine whatever transforms are necessary to convert from instrument coordinates to the IAS BOX coordinate frame in mm.

Once the transform is known the mapping proceeds as follows:

1) put the IAS GPROBE on the BOX center;

```
ORIGIN 0,0
GPROBE POSITION SET 0,0
```

2) Acquire an object in the GPROBE camera.

3) Move the NIR to several positions to locate the center of rotation. (If position of the rotation center is already known we can omit this step).

4) Set the rotator angle to 0 (zero) and turn NIR tracking off.

5) Correct telescope pointing to place the image at the center of rotation.

6) Remove the probe (GPROBE PARK) and measure the location of the image on the instrument.

7) Move the rotator some angle (say 45d). Return the probe to the center.

8) Repeat steps 5 through 7 recording the image positions through 360d of rotator angle.

For a non-imaging instrument an analogous procedure will have to be determined. As an alternate to measuring the image position with the instrument, the telescope pointing can be corrected to return the image to the center of the instrument at each rotator angle, and the image position measured with the GPROBE.

7. IAS display page

Whenever an CLI command is executed the IAS display page will be updated by painting the current (last measured) axis position in reverse video to indicate the position is not equal to the command.

The process then queries the IAS status. When the returned IAS status matches the commanded status, the displayed position video returns to normal.

Certain IAS devices (DARK SLIDE, FEED SLIDE, GPROBE, GPROBE, OR THE ADC SLIDE when not in position) can interrupt the light beam to the instrument. When any of these axes are in a position that obscures the beam to the instrument the device name is displayed in reverse video.

IAS status	ok, [estop]	
Flexure tracking	on, off	
MODE	BASE, EQUATORIAL, ECLIPTIC, GALACTIC	
POWER	12V on, off	ok
	5v on, off	ok
DARK SLIDE	out, in	ok
GUIDE PROBE		
RA, X	DD MM SS.S or MMM.M	ok
Dec, Y	DD MM SS.S or MMM.M	ok
Radius	DD MM SS.S or MMM.M	
Focus	FF, FFF	ok
Filter wheel	clear, nd, [dark]	ok
Color wheel	clear, red, blue	ok
Focus tracking	on, off	
FOCUS PROBE		
RA, X	HH MM SS.S or MMM.M	ok
Dec, Y	DD MM SS.S or MMM.M	ok
Radius	DD MM SS.S or MMM.M	
Focus	FF, FFF	ok
Filter wheel	clear, nd, [dark]	ok
Color wheel	clear, red, blue	ok
Pupil wheel	clear, split, INSIDE, OUTSIDE	ok
Focus tracking	on, off	
ADC	out, in	ok
lens A pos	AA.A	ok
lens B pos	BB.B	ok
Dispersion	DD.D	
ADC tracking	on, off	
FEED SLIDE	instrument, CIA-WFScam	ok
CIA		ok
Filter	clear, pos2, pos3, pos4	ok
Lamp1 (HeNe)	off, [on]	ok
...		ok
Lamp8 (Th-Ar)	off, [on]	ok
WFSCAM		ok
RA, X	HH MM SS.S or MMM.M	
Dec, Y	DD MM SS.S or MMM.M	
Radius	DD MM SS.S	ok
Focus	FF, FFF	ok
Filter wheel	clear, POS2, POS3, POS4	ok

Appendices

A. Coordinate transforms

Converting sky coordinates to X,Y coordinates in the BOX and BASE frames involves:

1) Convert from spherical to tangent plane coordinates.

2) Convert from tangent plane to the rotated NIR coordinates (corrects for rotator offset angle).

3) Convert from NIR coordinates to BOX correcting for field distortion and plate scale terms.

4) convert from BOX to BASE coordinates.

The ADC field corrector has the effect of changing both the plate scale and field distortion, so the process must reserve coefficients for both the bare system with ADC.

A.1 Spherical to tangent plane conversion

Star link gives the following subroutine for the conversion.

```
      SUBROUTINE DS2TP(RA,DEC,RAZ,DECZ,XI,ETA)
*
*
*   PROJECTION OF SPHERICAL COORDINATES ONTO TANGENT PLANE
*   ('GNOMONIC' PROJECTION - 'STANDARD COORDINATES')
*
*
*   GIVEN:
*      RA,DEC      SPHERICAL COORDINATES OF POINT TO BE PROJECTED
*      RAZ,DECZ    SPHERICAL COORDINATES OF TANGENT POINT
*
*   RETURNED:
*      XI,ETA      RECTANGULAR COORDINATES ON TANGENT PLANE
*

       IMPLICIT DOUBLE PRECISION (A-H,O-Z)

       DOUBLE PRECISION RA,DEC,RAZ,DECZ,XI,ETA


       SDECZ=SIN(DECZ)
       SDEC=SIN(DEC)
       CDECZ=COS(DECZ)
       CDEC=COS(DEC)
       RADIF=RA-RAZ
       SRADIF=SIN(RADIF)
       CRADIF=COS(RADIF)
```

```
      DENOM=SDEC*SDECZ+CDEC*CDECZ*CRADIF

      XI=CDEC*SRADIF/DENOM
      ETA=(SDEC*CDECZ-CDEC*SDECZ*CRADIF)/DENOM

      END
```

A.2 Tangent plane to spherical conversion

```
dtp2s.f          702312404   24505 24505 100755  831
`       SUBROUTINE sla_DTP2S (XI, ETA, RAZ, DECZ, RA, DEC)
*+
*     - - - - - -
*      D T P 2 S
*     - - - - - -
*
*  Transform tangent plane coordinates into spherical
*  (double precision)
*
*  Given:
*     XI,ETA      dp   tangent plane rectangular coordinates
*     RAZ,DECZ    dp   spherical coordinates of tangent point
*
*  Returned:
*     RA,DEC      dp   spherical coordinates (0-2pi,+/-pi/2)
*
*  Called:        sla_DRANRM
*
*  P.T.Wallace   Starlink   June 1989
*-

      IMPLICIT NONE

      DOUBLE PRECISION XI,ETA,RAZ,DECZ,RA,DEC

      DOUBLE PRECISION sla_DRANRM

      DOUBLE PRECISION SDECZ,CDECZ,DENOM,RADIF



      SDECZ=SIN(DECZ)
      CDECZ=COS(DECZ)

      DENOM=CDECZ-ETA*SDECZ
      RADIF=ATAN2(XI,DENOM)

      RA=sla_DRANRM(RADIF+RAZ)
      DEC=ATAN2(SDECZ+ETA*CDECZ,SQRT(XI*XI+DENOM*DENOM))

      END
```

A.3 Rotator offset transform

This applies a correction based on the offset of the NIR from the paralactic angle.

```
In:  XI, ETA    rectangular coordinates in tangent plane
     THETA           rotator offset (difference between rotator
                     angle and paralactic angle).
Out: X,Y        rectangular coordinates in IAS reference frame.

     X = XI*COS(THETA) - ETA*SIN(THETA)
     Y = XI*SIN(THETA) + ETA*COS(THETA)

     END
```

A.4 Removing rotator offset

```
In:  X,Y        rectangular coordinates in the IAS reference
                frame.
     THETA           rotator offset (difference between rotator
                     angle and paralactic angle).
Out: XI,ETA     rectangular coordinates in tangent plane.

      XI = X*COS(THETA) + Y*SIN(THETA)
     ETA = -X*SIN(THETA) + Y*COS(THETA)

     END
```

A.5 Distortion transform

Apply pincusion distortion and convert to mm along the curved focal plane

```
pcd.f          702312410   24505 24505 100755   1369
      SUBROUTINE sla_PCD (DISCO,X,Y)
*+
*     - - - -
*      P C D
*     - - - -
*
*  Apply pincushion/barrel distortion to a tangent-plane [x,y].
*
*  Given:
*     DISCO     d      pincushion/barrel distortion coefficient
*     X,Y       d      tangent-plane coordinates
*
*  Returned:
*     X,Y       d      distorted coordinates
*
*  Notes:
*
*  1)  The distortion is of the form RP = R*(1 + C*R**2), where R
```

```
is
*      the radial distance from the tangent point, C is the DISCO
*      argument, and RP is the radial distance in the presence of
*      the distortion.
*
*  2)  For pincushion distortion, C is +ve;  for barrel
distortion,
*      C is -ve.
*
*  3)  For X,Y in units of one projection radius (in the case of
*      a photographic plate, the focal length), the following
*      DISCO values apply:
*
*          Geometry          DISCO
*
*          astrograph         0.0
*          Schmidt           -0.3333
*          AAT PF doublet  +147.069
*          AAT PF triplet  +178.585
*          AAT f/8          +21.20
*          JKT f/8          +13.32
*
*   4)  There is a companion routine, sla_UNPCD, which performs
*       an approximately inverse operation.
*
*  P.T.Wallace   Starlink   11 April 1990
*-

      IMPLICIT NONE

      DOUBLE PRECISION DISCO,X,Y

      DOUBLE PRECISION F



      F=1D0+DISCO*(X*X+Y*Y)
      X=X*F
      Y=Y*F

      END
```

A.6 Removing field distortion

```
unpcd.f         702312413   24505 24505 100755  1862
`       SUBROUTINE sla_UNPCD (DISCO,X,Y)
*+
*     - - - - - -
*      U N P C D
*     - - - - - -
*
*  Remove pincushion/barrel distortion from a distorted [x,y]
*  to give tangent-plane [x,y].
```

```
*
*  Given:
*     DISCO    d      pincushion/barrel distortion coefficient
*     X,Y      d      distorted coordinates
*
*  Returned:
*     X,Y      d      tangent-plane coordinates
*
*  Notes:
*
*  1)  The distortion is of the form RP = R*(1 + C*R**2), where R
is
*      the radial distance from the tangent point, C is the DISCO

*      arguments, and RP is the radial distance in the presence
of
*      the distortion.
*
*  2)  For pincushion distortion, C is +ve;  for barrel
distortion,
*      C is -ve.
*
*  3)  For X,Y in "radians" - units of one projection radius,
*      which in the case of a photograph is the focal length of
*      the camera - the following DISCO values apply:
*
*          Geometry          DISCO
*
*          astrograph         0.0
*          Schmidt           -0.3333
*          AAT PF doublet  +147.069
*          AAT PF triplet  +178.585
*          AAT f/8          +21.20
*          JKT f/8          +13.32
*
*   4)  The present routine is an approximate inverse to the
*       companion routine sla_PCD, obtained from two iterations
*       of Newton's method.  The mismatch between the sla_PCD
*       and sla_UNPCD is negligible for astrometric applications;

*       to reach 1 milliarcsec at the edge of the AAT triplet or
*       Schmidt field would require field diameters of 2.4
degrees
*       and 42 degrees respectively.
*
*  P.T.Wallace   Starlink   20 April 1989
*-

      IMPLICIT NONE

      DOUBLE PRECISION DISCO,X,Y

      DOUBLE PRECISION CR2,A,CR2A2,F
```

```
      CR2=DISCO*(X*X+Y*Y)
      A=(2D0*CR2+1D0)/(3D0*CR2+1D0)
      CR2A2=CR2*A*A
      F=(2D0*CR2A2*A+1D0)/(3D0*CR2A2+1D0)
      X=X*F
      Y=Y*F

      END
```

A.7 Zenith distance and direction

B. Orthogonality corrections

The IAS process calculates corrections for non-orthogonality of a given stage axis to the IAS coordinates. The general form of this correction is a rotational transform about the IAS Z axis by an angle phi.

```
IN:  X,Y  coordinates referenced to IAS frame
     phi  angular misalignment of the stage from the IAS
          coordinate frame
OUT: Xs,Ys     coordinates in stage reference frame

     Xs = X*cos(phi) - Y*sin(phi)
     Ys = X*sin(phi) + Y*cos(phi)
```

The IAS process will maintain a matrix of correction angles for these devices:

- Fprobe X & Y axes
- Gprobe X & Y axes
- WFScam X axis

Note: this transform neglects non-perpendicularity between the Xs-Ys stages. The stage were purchased as precision aligned orthogonal pairs, so we do not anticipate any need for non-perpendicularity corrections.

C. Atmospheric dispersion model

[this section is still in progress - dan]

Liang Ming supplied the following equation for modeling the dispersion introduced by the atmosphere:

```
IN:    LAMBDA            median wavelength (microns)
          P              Atmospheric pressure in mm Hg
          T              Air temperature in Celsius
          ZEN            Zenith distance (compliment of elevation
```

angle)

Note: for standard atmosphere use P = 592.7 and T = 1.5

```
Out: DIFF      ADC stage difference angle
          DISP      Dispersion in arcseconds

N_REF = 1+1E-6*(64.328 + 29498.1/(146 - LAMBDA^-2) + 255.4/(41 -
LAMBDA^-2)

'     N_REF is the refractive index of air at wavelength LAMBDA

DISP = 206265*(N_REF-1)*TAN(ZEN)*P/(760+2.9*T)

'     A single ADC prism can produce 0.33 mm (3.05 arcseconds) of
      dispersion
'     over the range 3500 to 10140 Angstroms.

ALPHA = ACOS(DISP/2/3.05)

'     ALPHA is the angle of one ADC stage away from the base
      angle.
```

D. Focus tracking

Find focus offset based on position to follow a curved image surface. Used for focus tracking.

```
IN:     X,Y           DEVICE LOCATION IN IAS COORDINATES
     ADC_S            ADC SLIDE STATUS (0 = OUT, 1 = IN)
OUT:    F        OFFSET FOR DEVICE FOCUS STAGE

     P = ADC_S*2115
     R = SQR(X^2 + Y^2)
     F = P - SQR(P^2 - R^2)
```

NOTE: image surface curvature p is 2115 mm with ADC SLIDE out, 0.0 with ADC SLIDE in.

E. Error codes