NICI Mechanism Top Level Functional and Performance Requirements

NICI System Design Note # SDN1001

By Douglas Toomey 1/18/02 Revision 1.1

1.0 **Introduction**

This document will specify the functional requirements of the NICI instrument in terms that would effect operation and identify measurable performance requirements and goals. This document will be used by software and hardware engineers as a basis for a more detailed specification of these mechanisms.

2.0 **Mechanism Overview**

NICI has 10 mechanisms divided between the three major subassemblies. The table below lists the mechanisms and is followed by brief descriptions of each mechanism. The remaining sections will give detailed functional and performance specifications for each mechanism.

Mechanism	#of Positions	Type of drive
AO Relay		
Fiber optic calibration source	4	Four position translator
Wavefront Sensor		
Tip/tilt steering mirror	continuous	Two angle tilt mirror
Neutral density filter wheel	6	Discrete position wheel
Cryostat		
Focal Plane Mask wheel	8	Continuous rotary wheel
Spider Mask Rotator	continuous	Continuous rotary drive
Pupil Mask Wheel	8	Discrete position wheel
Beam splitter/dichroic wheel	15	Discrete position wheel
Channel 1 filter wheel	22	Discrete position wheel
Channel 2 filter wheel	22	Discrete position wheel
Pupil imager	3	Discrete position wheel

Fiber optic calibration source - This translator has four positions and is used for calibration and checkout of the instrument as well as providing a “while integrating” position calibration source. This mechanism will block off the incoming light aperture so it will also function as a “dust cover” when in position one. The table below gives the information for each position.

Position #	Source type	Note
1	Single centered fiber	Home, dust cover closed
2	5x5 matrix of fibers	
3	2 corner fibers	
4	open	

The fibers will be single mode type. Position one will be used to calibrate the AO system and for checkout of the camera. Position 2, the fiber matrix, will be used to map the channel 1 IR detector to the channel 2 IR detector and to measure distortion. The third position, the 2 corner fibers, will be used with faint illumination while integration on a science object to give constant registration Position 1 is the home position. When in position one the input optical path hole is closed off to prevent dust infiltration so this is the stow position as well as the home position.

There is a lamp to illuminate the fibers. Variable illumination is required to deal with different filters and different integration times. Zero to ten volts with a resolution of 8 bits is adequate.

It would be desirable for the slide to home and position to 1/10 of the image core(lambda/D). In the J filter the image core is 0.036 (20 microns) so the desired home accuracy, reproducibility, movement due to flexure and hysteresis is 2 microns.

Time to move from position 1 to position 4 should be less than 30 seconds.

Tip/tilt steering mirror - This mechanism is a tip/tilt, or two angle, mirror that is used to center the star image in the wavefront sensor 5 arcsecond field of view. This mirror will be adjusted when dithering more than 2 arcseconds or when guiding on an off axis object. When dithering the steering mirror will be moved in a coordinated motion with the focal plane mask wheel. It will allow guiding over the entire 18 arcsecond diameter field. It may also be used for flexure correction and atmospheric refraction . The home position will be an offset form the hardware zero,zero position. This offset from hardware zero position will be defined by two variables set through the engineering interface. The following parameters are required for the steering mirror.

Maximum tilt on the sky	+- 9 arcseconds
Step size on the sky	+- 0.0018 arcseconds
Stability on the sky	+-0 .0018 arcseconds
Hysterisis on the sky	+- 0.0018 arcseconds
Maximum tilt angle at mirror	+- 0.3 degrees(not final)
Step size at the mirror	+- 0.2 arcseconds
Update rate	~1 Hz

The steering mirror is commanded with two analog voltages fed by two D/A contverters. The mirror gives position feedback through two analog voltages that are read via A/D converters. These converters must have at least 5,000 steps of useful resolution which is >12 bits(4096). The input and output range for the steering mirror is +- 10 volts.

Details of hardware – The tilt mirror will be an off the shelf package purchased from Ball Aerospace, see http://www.ball.com/aerospace/fsmarticle.html It is a voice coil, Kaman sensor design. It has two analog inputs +/- 10 volts and two analog outputs that give position. An A/D and D/A will have to be provided to read and command the mirror.

Neutral density filter wheel - The brightness of the guide objects will range from extremely bright to very faint. This wheel will be equipped with neutral density filters to reduce the guide star flux to levels appropriate for the avalanche photodiodes in the wavefront sensor. A red filter will also be included to improve signal to noise on reddish guide objects when the moon is up. The control program for this wheel will check APD counts and not execute a move if the new filter would result in counts above a set threshold. The home and stow positions are the darkest ND filter. The planned filter wheel population is shown in the table below.

Neutral Density Filter Wheel Layout

Position	Filter	notes
1	Blank	Home, Stow
2	ND4	
3	ND3	
4	ND2	
5	Red	
6	Spare(blank until used)	

Focal Plane Mask Wheel - The observer will be able to choose from one of 8 focal plane masks. These masks will be in a wheel and selected by rotating the wheel. The drive will be continuous so the masks can be positioned along an arc in the image. This allows one dimensional dithering. There is a single homing magnet on the wheel. The home and stow position is the blank.

Homing accuracy	20 microns(Lambda/D at J at mask face)
Mask position accuracy	20 microns
Step size	2 microns
Backlash	2 microns

Position	Mask	notes
1	Blank	Home and Stow
2	0.1 arcseconds	
3	0.2 arcseconds	
4	0.3 arcseconds	
5	0.4 arcseconds	
6	0. 5 arcseconds	
7	User position	
8	User Position	

One of the focal plane mask positions will provide a calibration mask. Three positions will provide standard stellar masks of different sizes. One position will be used for the grism slit, one for a calibration mask and the remaining position will be for observer supplied masks. The mask will be selected by positioning the wheel to the correct position for the selected mask. One dimensional dithering is then accomplished by small movements of the wheel. The startup and shut down position is the calibration mask.

This wheel will need good backlash performance and possibly backlash software correction. Time to move from position 1 to position 4 should be less than 30 seconds.

Spider Mask Rotator - The spider mask is a cross shaped mask that aligns with the spider image in the cryostat. The mask must be rotated to stay aligned with the telescope spiders when the instrument rotates to de-rotate the field. The alignment of the spider mask will be automatic. Once the observer selects that the spider mask mechanism is active, it will look up the telescope rotator position and position itself accordingly. The startup and shut down positions do not matter and can be set to 0 degrees. There will be a single home magnet in the rotator for a home position

The spider mask width will be 30 times the size of the reimaged spiders with the emissivity lowering reflectors installed. These reflectors are 11mm wide on the 8,000 mm entrance pupil. This means that the spider mask covers a width of 4.7 degrees at the edge of the pupil. For a step size of 1% of the spider mask, the required step size is 170 arcseconds. The desired backlash or hysterisis is the same 170 arcseconds. For most Dec. positions the maximum rate of change in the rotator position is 2 degrees/minute or less. Near the zenith the rate can be as high as degrees/minute.

Pupil Mask Wheel - The pupil mask wheel allows the selection of a pupil plane mask from a choice of eight masks. The pupil plane mask stops down the outer edge and inner edge of the image of the secondary. For instance, the outer edge maybe stopped down to 90% of the full telescope pupil image. A similar area is masked around the inner hole(10%). This is a detented wheel with the blank at the home position. The wheel population is shown in the table below. Positioning accuracy is 1% of the pupil diameter or 120 microns.

Pupil Mask Wheel Layout

Position	Mask	Notes
1	Blank	Home, Stow
2	95:5	
3	90:10	
4	85:15	
5	80:20	
6	Apodized mask 1	
7	Apodized Mask 2	
8	Spare	

.

Beam splitter/dichroic wheel - This wheel has 15 positions that determine which wavelengths are sent to each IR channel. Different experiments will require that the beamsplitting wavelength change. This is a very critical mechanism for NICI. It is the only science beam optical element mechanism that can steer the beam so stability of this wheel is of high importance. The following are the positional stability requirements:

Allowable tilt due to flexure when in detent	1.2 arcseconds(1/5 pixel)
Allowable radial translation when in detent	5 microns(1/5 pixel)
Allowable rotary motion when in detent	1.2 arcseconds (1/5 pixel)
Positional reproducibility	27 microns(1 pixel)
Absolute tilt between dichroics	5 arcminutes(50 pixels)

The table below shows the planned(although not necessarily budgeted) population of the beam splitter/dichroic wheel.

Channel Splitting Elements – Dichroics			
	Channel 1 Response	Channel 2 Response	Name
Position #1	< 1.8 microns	> 1.9 microns	H/K
Position #2	< 4.2 microns	> 4.4 microns	L/M
Position # 3	1.2-1.4 microns	1.4-1.7 microns	H- Methane
Position #4	2.0-2.15 microns	2.15-2.3 microns	K-Methane
Position #5	< 3.6 microns	>3.7 microns	L- Methane
Neutral Density Elements			
	Channel 1 Response	Channel 2 Response	Name
Position #6	50% 1.0-2.4 microns	50% 1.0-2.4 microns	50/50 Short
Position #7	50% 3.3-4.9 microns	50% 3.3-4.9 microns	50/50 Long
Calibration/Maintenance Elements			
	Channel 1Response	Channel 2 Response	Name
Position # 8	100%	0.	Hole
Position # 9	0%	100%	Mirror
Line/Continuum Elements			
	Channel 1 Response	Channel 2 Response	Name
Position #10	1.6 microns	Continuum	Methane
Position #11	1.64 microns	Continuum	[FeII]
Position #12	2.122 microns	Continuum	H2 1-0 s (1)
Position #13	2.166 microns	Continuum	Bracket Gamma
Position #14	Spare(open until used)		
Position #15	Spare(blank until used)		

Channel 1 filter and Channel 2 filter wheels - Each channel will have a filter wheel with 22 filter locations. . Since the 50/50 beam splitters allow the reversing of the long and short channels, the initial complement of filters will be nearly the same in each wheel. The table below lists the layout for each wheel. The planned initial complement of filters that will be shipped with the instrument are indicated with a *. Filters at the other locations will be added by Gemini at a later time. A blank-off and an open position will be used initially for testing.

Filter Position #	**Channel 1 Wheel**	**Initial Complement**	**Channel 2 Wheel**	**Initial Complement**
1	Blank-off(home)	*	Blank-off(home)	
2	J	*	J	*
3	H	*	H	*
4	K'	*	K'	*
5	L'	*	L'	*
6	M'	*	M'	*
7	H methane on		H methane on	
8	H methane off		H methane off	
9	K methane on	*	K methane on	*
10	K methane off	*	K methane off	*
11	L methane on		L methane on	
12	L methane off		L methane off	
13	J age filter 1		J age filter 1	
14	J age filter 2		J age filter 2	
15	[FeII]		[FeII]	
16	[FeII] cont.		[FeII] cont.	
17	H2 1-0 s(1)	*	H2 1-0 s(1)	*
18	H2 1-0 s(1) cont.	*	H2 1-0 s(1)cont.	*
19	Br gamma	*	Br gamma	*
20	Br gamma cont.	*	Br gamma cont.	*
21	Grism 1		Grism 3	
22	Grism 2		Grism 4	

The filter wheel is a detented mechanism so the accuracy issues key on the detent accuracy. The filters are in the collimated beam so positional requirements are relaxed..

Home accuracy – +/-0.25 mm
Detent positional accuracy/repeatability – +/- 0.25 mm
Time to rotate half the wheel – 30 seconds

Pupil imager- A pupil imaging mode has been included as a diagnostic function. Using the pupil imager will allow the alignment of NICI with the telescope to be checked as well as the alignment of the pupil plane mask, spider mask filters, and dichroic wheel. Normally the observer will not use the pupil imager for typical science projects. There are three positions. The first is the open position followed by the blank position and the third is the pupil imaging lens position. This lens makes an image of the lyot stop about 150 pixels across on the IR array. The home/stow position is the open position.

Positional accuracy – 0.27 mm (10 pixels)