1-1-1994

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Kemp, John C., Harry O. Ames, Roy W. Esplin, and Glenn D. Allred. 1994. "WIRE Instrument Description: Focal Planes, Optics, and Electronics." *Proceedings of SPIE* 2268: 56–67. doi:10.1117/12.185856.

Invited Paper

WIRE instrument description: focal planes, optics, and electronics

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ABSTRACT

An elegantly simple cryogenic instrument has been proposed to measure far infrared radiation from starburst galaxies. The experiment—known as WIRE—employs a Cassegrain telescope with diamond-turned mirrors to provide a light-weight optical system for photon collection. A dichroic beamsplitter and filter separate the light into two broad, well-defined bands of interest. Two 128- x 128-pixel arsenic-doped silicon focal plane arrays spatially sample the incoming photons. These arrays feature exceptionally low dark current and low read noise, which allows the coaddition of thousands of images. The entire optical section and focal plane arrays are cooled to 12 Kelvin and 7.5 Kelvin, respectively, by a two-stage, solid-hydrogen cryostat. An uncomplicated electronics package provides some on-board coaddition of images, accepts the simple commands required by the WIRE instrument, and interfaces the data signals to the SMEX spacecraft for telemetry to the ground.

1.0 INTRODUCTION

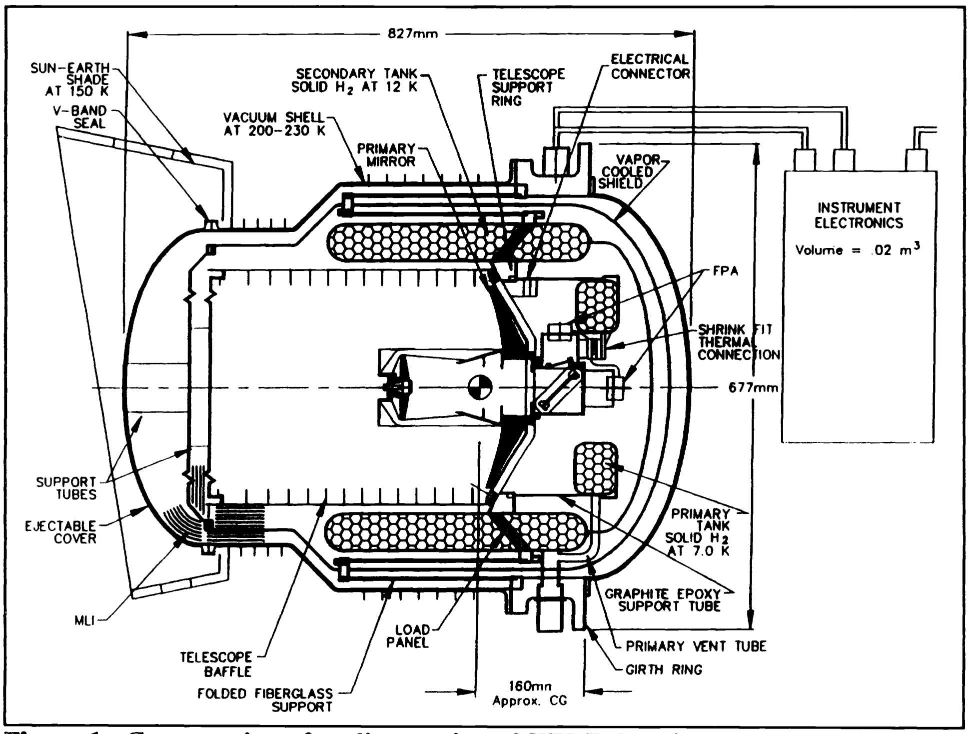


Figure 1. Cross section of earlier version of WIRE, locating telescope within two-stage solid-hydrogen cryostat.

WIRE (*w*ide-field *i*nfra*r*ed *e*xplorer) is one of four candidate payloads, two of which NASA plans to launch as early as November 1997 as part of a second group of its *sm*all *ex*plorer (SMEX) satellite missions. It is designed to measure infrared radiation from starburst galaxies using two broad, super-sensitive, long-wave infrared bands. Science and mission operations for WIRE are discussed separately by Hacking *et al*. at this conference. The WIRE instrument is enclosed in a solid-hydrogen-cooled cryostat, which is described by Batty *et al.*, 1994. Figure 1 shows a cross section of the WIRE instrument with the telescope located within the hydrogen cryostat. This instrument is attached to the SMEX spacecraft by means of four bipod struts, which can be seen in figure 2; the figure also summarizes many of the mission's critical specifications.

0-8194-1592-8/94/$6.00

BASIC DESCRIPTION

Wire is a two-color, solid hydrogen cooled, imaging telescope operated in low earth orbit for 4 months to study evolution of starburst galaxies

Parameter	Baseline
Total Mass	275 kg*
Total Power	215 W estimate
Instrument Mass	70.6 kg
Instrument Power	<35 W
Size	74.9 cm (dia) x 93 cm Fits in Pegasus

* Includes 25% instrument mass margin

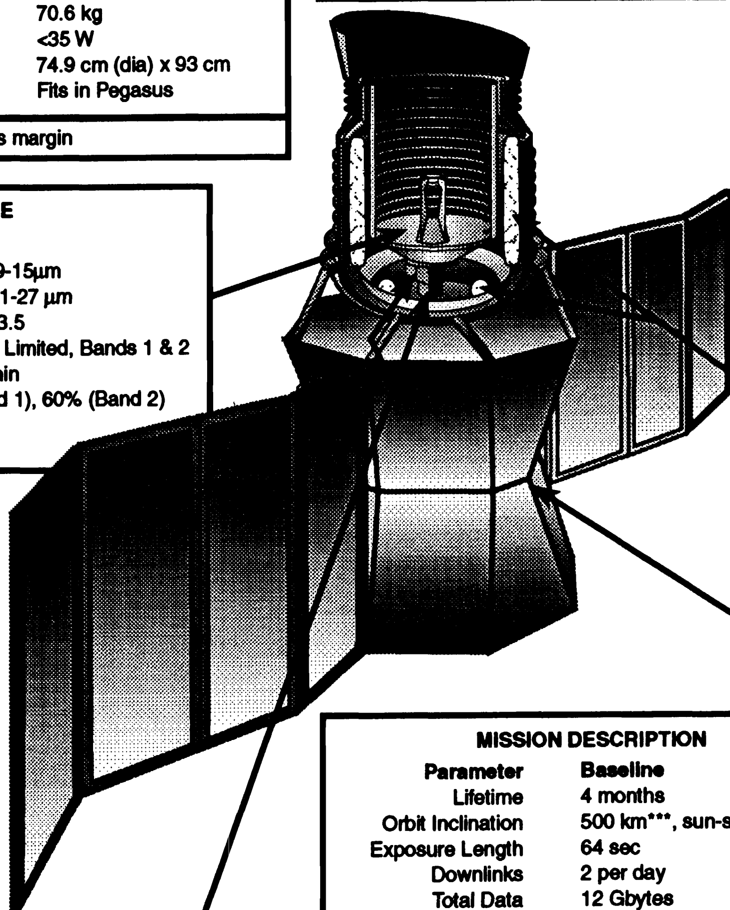
OBJECTIVE OF WIRE

To answer three questions:

(1) What fraction of the luminosity of the Universe at a redshift of 0.5 and beyond is due to starburst galaxies?
(2) How fast and in what ways are starburst galaxies evolving?
(3) Are luminous protogalaxies common at redshifts less than 3?

TELESCOPE

Parameter	Baseline
Spectral Range	Band 1: 9-15µm Band 2: 21-27 µm
Aperture	30 cm, *f*/3.5
Image Quality	Diffraction Limited, Bands 1 & 2
Field of View	31.6 arc min
Transmission	68% (Band 1), 60% (Band 2)
Optics Temp	13 Kelvin
Mass	12.8 kg



KEY SCIENCE REQUIREMENTS

Parameter	Baseline
Sensitivity, 25 µm	RMS Confusion Noise = 0.051 mJy Instrumental Noise = 0.043 mJy in 9 hours
Sensitivity, 12 µm	$Noise_{Total}$ ~ 0.012 mJy
Sky Coverage	135 deg^2
Sources detected	>30,000
Typical distances	z≈0.5

*Confusion limited implies Instrumental Noise < Confusion Noise

CRYOSTAT

Parameter	Baseline
Type	Dual stage, Solid Hydrogen
Mass	47.4 kg
Primary Tank Temp	<7 K
Secondary Tank Temp	12 K
Primary Tank Hydrogen Mass	0.4 kg
Secondary Tank Hydrogen Mass	3.3 kg

FOCAL PLANE ARRAYS

Parameter	Baseline
Format	128 x 128 pixels (75 µm)
Pixel Size	1.5 pixel/ FWHM→14.8 arc sec
Dark Current	750 e^-/sec
Quantum Efficiency	>0.25
Read Noise	<50 RMS e^-/pixel
Temperature	7.5 Kelvin

MISSION DESCRIPTION

Parameter	Baseline
Lifetime	4 months
Orbit Inclination	500 km***, sun-synchronous
Exposure Length	64 sec
Downlinks	2 per day
Total Data	12 Gbytes
Observing Efficiency*	51%
Sun Avoidance	>80°
Earth Avoidance	>150°
Moon Avoidance	>20°**

*On primary targets
**During observations
***Includes 25% mass margin

SPACECRAFT (SWAS Bus)

Parameter	Baseline
Mass	174.2 kg
Power	180W average
Solar Panels	Deployed GaAs
Pointing Accuracy (2σ, radial)	2 arc min
Pointing Stability (2σ, radial)	12 arc sec
Average Data Rate	9 kbits/sec

Figure 2. Wide-field Infrared Explorer (WIRE) Fact Sheet

This paper describes several of the key elements of the proposed WIRE instrument, including the telescope that collects the photons and discriminates them based on their wavelengths; the focal plane arrays (FPAs) that convert the photons into electrons and electrical signals; and the electronics that collect, organize, and transmit the electrical signal to the spacecraft. There are no moving parts in the WIRE instrument.

2.0 TELESCOPE

Figure 3 is a sectional view of the telescope. It shows a relatively uncomplicated optical system that is simple enough to allow a reasonable set of variables for optimization (too many variable options can turn fine tuning into a nightmare). We intend to use a Ritchey-Chretien on-axis Cassegrain configuration that imposes a weak hyperbolic shape on both the primary and secondary mirrors. The mirrors will be clamped and pinned in position after being adjusted with an alignment jig. Diffraction-limited performance will be achieved in both spectral bands. The total mass of the telescope is expected to be 12.8 kg.

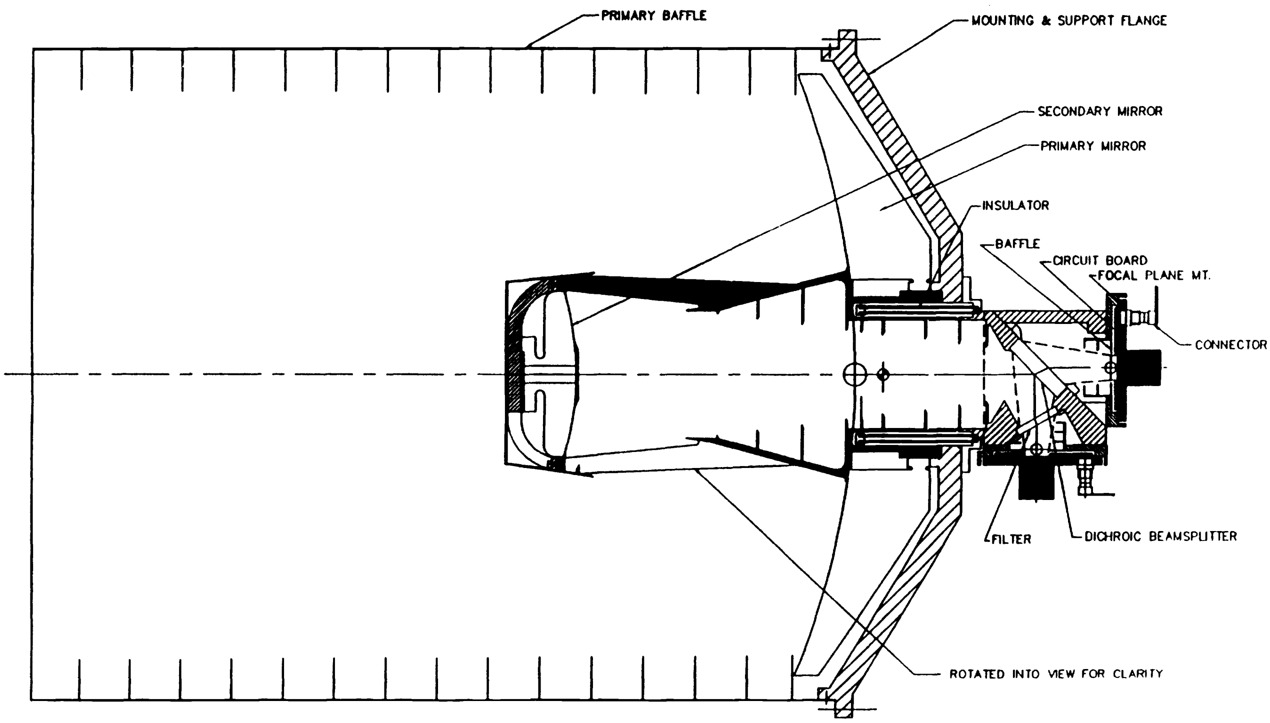


Figure 3. Sectional view of Cassegrain telescope with Meinel secondary supporting system.

We have used the Meinel configuration where the secondary mirror is braced by supports that are attached to the inside of the primary mirror. Supports attached to the outside of the primary would have required a larger diameter (and heavier) cryostat for the same diameter primary. Not only does this configuration minimize the weight of the total instrument, it is also ideal from the standpoint of being a simple system with few independent parts; in addition, it provides a simple thermal path for cooling. By fabricating the entire instrument from thermally cycled 6061-T6 aluminum, we have also been able to minimize any thermal distortions caused by cooling.

Three vanes will be used for the secondary mirror supports. These lead to a six-point diffraction pattern that produces less energy in the wings than would be produced by a four-point pattern if four vanes were used. There are additional advantages to a three-vane system, as well: it has a cleaner mechanical adjustment than a four-vane system, and for the same vane thickness, the three-vane mount has a lower fundamental mode of vibration—an important fact when designing for ruggedness to survive a rocket launch environment.

Mirrors and mirror mounts. The mirrors will be diamond turned to eliminate the bimetallic effect that occurs in standard post-polished mirrors. The diamond-turning process is also less expensive than the post-polishing process and produces a surface accuracy that is sufficient for the WIRE wavelength regions. To provide a rugged, cleanable surface (the mirrors can be removed for cleaning), the diamond-turned mirrors will be coated with Denton gold. As part of the final design process, Utah State University's Space Dynamics Laboratory (SDL/USU) plans to measure the bidirectional reflectance distribution function (BRDF) of sample diamond-turned mirrors. If a straylight analysis of the measured BRDF shows that straylight is too large, SDL/USU will employ a backup configuration using post-polished mirrors that have a thin nickel coating underlying the gold overcoat.

By using a stress-relieving connecting "neck" between the mirror and the mounting surface, the mounts are designed to prevent any mounting-stress "print through" to the mirrors themselves Each mirror is mounted on three raised, lapped pads, which minimizes the thickness of the mirror mount compression column. The mirror thickness is sufficient enough so that the centrifugal force distortion is negligible, and—as noted earlier—the tapered shape of the primary mirror minimizes its weight. It is estimated that the error in the figure of the 330-mm diameter primary mirror will be one to two waves at 0.63 μm, with a surface roughness of 100 to 200 Å rms. The 91.3-mm diameter secondary mirror is estimated to have a figure error of one-fourth to one-half wave, with a surface roughness of 100 to 150 Å rms. The central obscuration is 18 percent of the entrance area.

Beamsplitter and filters. The two spectral passbands are achieved by using a silicon dichroic beamsplitter that transmits long wavelengths and reflects shorter ones. The shorter wavelength band is defined by an interference filter. The filter is mounted at an angle of 30 degrees to prevent any reflected light from the focal plane array from being redirected back to it. The short-wavelength cut-on of the long-wavelength band is determined by the transmittance cut-on of the dichroic. The long-wavelength band edge is determined by the cut-off of the arsenic-doped silicon, blocked-impurity band (Si:As BIB) detectors. Both the beamsplitter and the filter are wedged to ameliorate the astigmatic effect of plates in a convergent beam.

Silicon was chosen as the substrate for the dichroic because it is a very strong and robust optical material and allows a rather large (11.6 to 1) aspect ratio without significant surface deformation taking place. Serendipitously, the strong absorption band of silicon at about 16 μm happens to fall within the reflective region of the dichroic and is thus not a factor in the dichroic's performance. The variation in index of refraction within the 22–27 μm band is very small, which leads to negligible chromatic aberrations from the dichroic. The transmittance of silicon is quite flat over the required transmission band when used at a temperature of 10 Kelvin.

Cadmium-telluride (CdTe) and indium-antimonide (InSb) are commonly used as substrates in the long-wavelength regions and were considered for use as the WIRE detector substrate. However, CdTe is very difficult to use because of its poor mechanical properties, including an inadequate resistance to coating stresses. InSb, meanwhile, has a long-wavelength cut-off that falls within that of the Si:As detectors, and this reduction would significantly reduce the sensitivity of WIRE's detectors.

Figure 4 (right) shows a blowup view

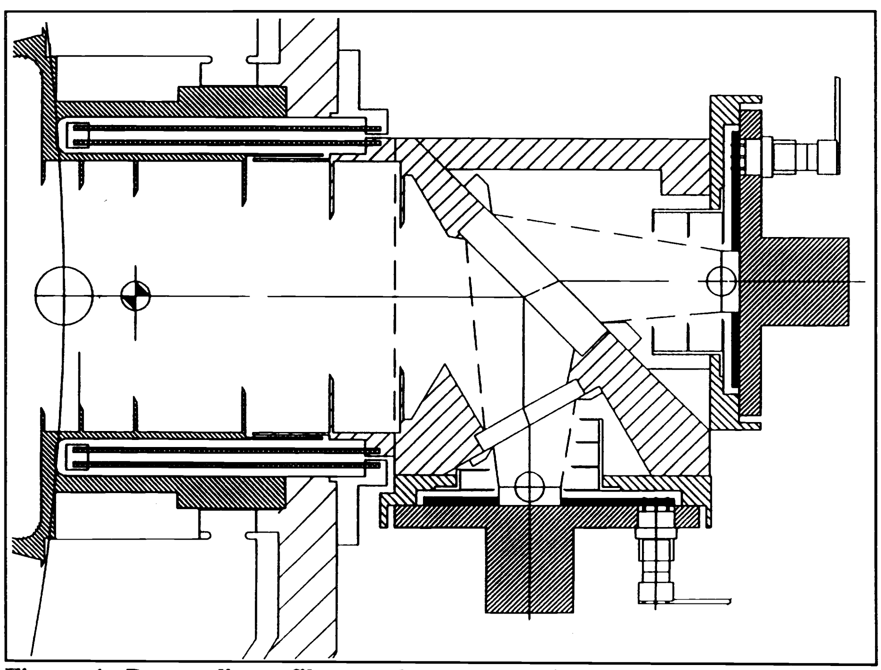


Figure 4. Beamsplitter, filter, and FPA mounting structure showing internal baffling.

of the beamsplitter and the filter mounted within the optics "cube." The baffles shown around the FPAs are there to eliminate any flat walls near the detectors that could cause side lobes in the WIRE field of view. Note the thermal isolation that has been designed between the structure that holds the beamsplitter, filter, and FPAs—cooled to 7.5 Kelvin—and the primary mirror and inside baffle structure—cooled to about 12 Kelvin. This design also provides a relatively large thermal mass for the FPAs that will tend to dampen out any fluctuations of FPA temperature. The FPAs and their mounts are described in later sections.

Baffling has been placed inside the primary baffle tube in front of the primary mirror and also in a cone extending part way between the primary and secondary mirrors and down inside the aperture through the center of the primary mirror (refer to figures 3 and 4). Because of the nature of the measurements WIRE will be making, straylight is not a critical consideration. There are two stimulation sources located within the central obscuration of the secondary mirror that can be used to stimulate the FPAs to check for functionality and also as an aid to flat fielding of the FPA response.

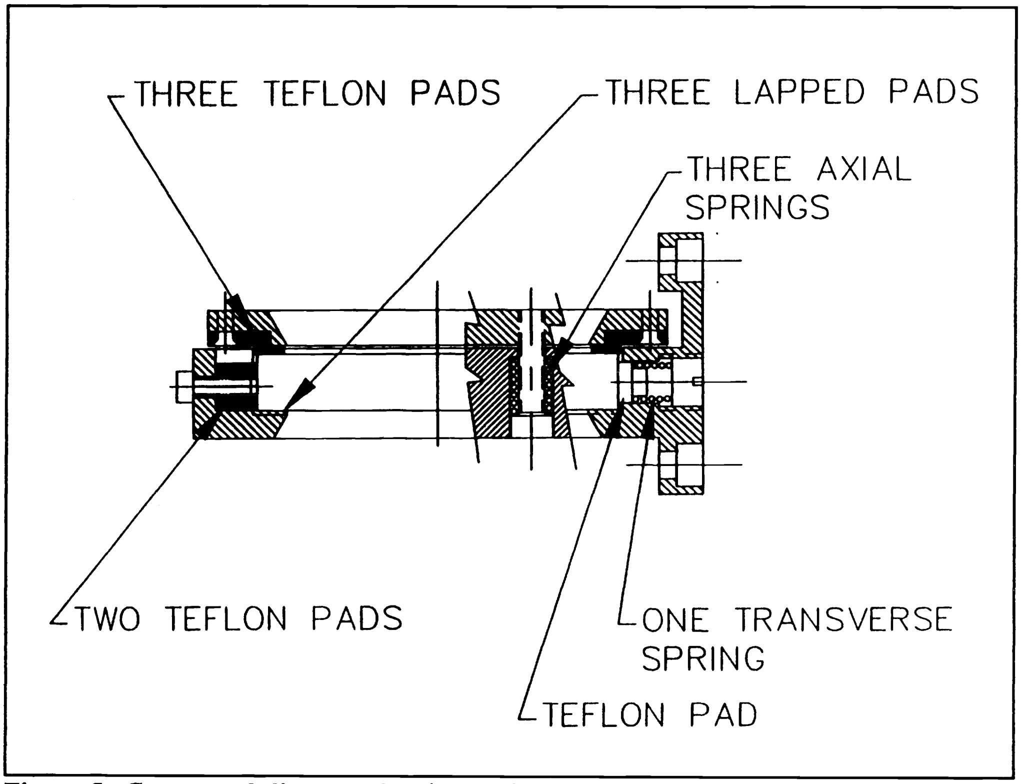


Figure 5. Conceptual diagram showing spring loading of beamsplitter and filter in their mounts.

Figure 5 (left) illustrates the mounting concept for the dichroic and filter. By means of three Teflon pads, three axial springs hold the optics against three lapped pads attached to the solid structure. One transverse spring working with a Teflon pad holds the optics radially against the other two Teflon pads. Spring constants and spring spacing have been chosen so that known amounts of loading can be applied by tightening screws. Proper loading is guaranteed by the use of mechanical constraints, not by how much torque is applied when the screws are tightened. This mounting system—which has been proved on both the SPIRIT III and SPAS III instruments—holds the optics sufficiently tightly to maintain alignment during the cooling process and during vibration and shock; it does so without overloading the optics and causing flatness distortion.

3.0 FOCAL PLANE ARRAYS

The photons collected by the WIRE telescope will be converted to electrons by two 128- x 128-pixel focal plane arrays. The detector material is arsenic-doped silicon laid out in a back-illuminated, blocked-impurity-band (BIBIB) configuration. First invented in 1979, BIB detectors were produced in a 10- x 50-pixel array format in 1985. They were subsequently used by SDL/USU in a 10- x 25-pixel (modified SEER) array configuration in the SPIRIT II program and in an 8- x 192-pixel (tall chip) configuration in the SPIRIT III program. They were first produced in the 128- x 128-pixel format in 1991 for independent research and development programs at Rockwell. The pixels are 75 micrometers square.[1] According to Herter *et al.*, 1987,

> Blocked-impurity-band detectors were originally developed at Rockwell to provide radiation-hardened devices [that] were free from many of the problems associated with extrinsic silicon photoconductors . . . . However, the benefits of these detectors extend further, eliminating much of the erratic behavior seen in the standard extrinsic photoconductor, i.e., spiking associated with bias changes and turn-on, reduced electrical and optical crosstalk, improved uniformity, and increased wavelength coverage. BIB detectors employ a thin, undoped epitaxial Si layer between a heavily doped infrared active layer and one of the planar contacts. The undoped blocking layer prevents dark current but does not impede the flow of current due to photoionization of neutral impurities in the active layer. Because of the blocking layer, BIB detectors behave in a fashion closer to that of reverse-biased photodiodes rather than standard photoconductor models.

The requirements for the WIRE detectors are similar to those for the planned *s*pace *i*nfrared *t*elescope *f*acility (SIRTF). Cornell University has been cooperating with Rockwell—the proposed WIRE FPA vendor—in evaluating the performance of hybrid BIBIB arrays as part of the SIRTF technology development program. The primary difference between the WIRE and SIRTF requirements is that the SIRTF detectors are to operate in a helium-cooled environment, which is about 3 degrees cooler than the WIRE detector environment. This temperature difference has a significant effect on dark current.

Rockwell engineers are seeking to understand the specific process parameters that lead to very low dark current measurements at higher temperatures. Sample detectors from the various detector lots developed over the years have been tested under WIRE conditions. A sample of detector material developed in one of the previous SIRTF development runs has been identified that meets the WIRE requirements. However, based on ongoing tests, one additional detector epitaxial batch will be produced in an attempt to further increase the performance margin by enhancing detector performance at the specific WIRE operating temperatures. It is believed that a factor-of-two improvement in detective quantum efficiency may be possible.

In addition to needing detector pixels with low dark currents, the other critical element for the WIRE focal plane array assemblies is a low-noise multiplexer that will read out the 16,384 pixels into four output lines in a noise-free manner. A low-noise, 128- x 128-pixel multiplexer using a switched field effect transistor (FET) as a source follower for each unit cell has been developed for use in astronomical applications. Various hardening techniques have been applied to produce multiplexers that are genuinely hardened to the total dose environment (R. A. Noel *et al.*, 1992). This design has been further optimized for low-flux operating conditions. The latest optimization included locating various power driver stages off the multiplexer chip into a separate satellite chip to move most of the power dissipative elements away from the hybrid. For a low-background application, this will ensure that any elements that could glow are kept away from the detectors and multiplexer elements, eliminating any possibility of self stimulation.[2]

The multiplexer is made entirely from silicon. Mating to the detector is accomplished by means of many indium-bump bonds between the detector chip and the multiplexer chip, which forms a hybrid device. Perfect

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1 For a thorough discussion of the blocked-impurity-band technology, refer to the article, "Blocked Impurity Band Hybrid Infrared Focal Plane Arrays for Astronomy," by D. H. Seib *et al.*, 1989. Also refer to the 1991 D. H. Seib *et al.* paper entitled, "Performance of 128 x 128 Element Switched Mosfet/Blocked Impurity Band Detector Hybrid Arrays."

2 Again, for a fuller treatment of this subject, see the paper by D. H. Seib *et al.* entitled "Advanced Multiplexed Readouts for T<15K Focal Plane Arrays."

thermal matching is achieved because both elements are silicon based. This bump bonding has been used successfully in a number of programs and forms stable, rugged hybrid elements.

The cryostat will hold the FPA at 7.5 Kelvin or lower. On orbit, the instrument will stare into a particular section of space for a period of 32 to 128 seconds, after which time it will be dithered a few pixels and will then perform another stare. It is anticipated that each target region can be observed for about 10 minutes during a particular orbit. On succeeding orbits, the same target region will be observed again until a total observation period of about 10,000 seconds is made for each target region. After being properly registered, these observations will be coadded.

Given this operating mode, we anticipate the following conditions and requirements for FPA performance: photon background is expected to range from 5,000 to 15,000 photons per second per pixel; detective quantum efficiency (eta/beta) needs to be 0.25 or greater; dark current, expected to be about 300 electrons per pixel per second, needs to be much less than the normal photocurrent from the expected background levels; read noise, expected to be about 50 electrons per read, needs to be much less than the photon noise from the expected signal levels; FPA dark current and offsets need to be very stable, otherwise the flat fielding needs to be very stable so that natural background limits can be achieved through the coadding process.

Experience gained in testing these arrays for use in ground- and aircraft-based astronomy indicates that usually there are perturbations when the FPA is operated under changing timing conditions, for example, when changing from one integration time to another. Therefore, it is desirable to operate the FPA in a regular, continuous fashion to ensure photometric stability and minimize noise. A maximum observing efficiency is desired for the WIRE mission, including those procedures that will produce short dithers (realignments) between staring segments. For FPAs tested so far, it appears that integration times longer than 4 seconds are sufficient to guarantee that the read noise is much lower than the photon noise.

The baseline operating mode is to run the FPAs at a 4-sec integration time and coadd onboard for the duration of the staring segment. This total data frame (approximately 64 seconds' worth) will then be sent to the spacecraft for telemetry to the ground. The 4 or 8 seconds of data taken during alignment dithering will be discarded, and a new frame of coadditions will begin after the spacecraft motion has settled out after the slewing of the dither. Coadding up to 16 integration times in this manner will greatly reduce the telemetry data rate while still producing the signal-to-noise ratio of a very long integration time. This, of course, assumes that the attitude control system of the spacecraft will maintain the required pointing stability during the staring segments.

Ground testing done at Cornell on the various detector samples has thus far indicated the need for an antireflection (A/R) coating that is deposited directly on the detector and is specific to the particular infrared band. This would boost the effective detective quantum efficiency by a factor of about 1.3, which is to the levels required to perform the mission measurements in a reasonable data-taking time. Applying an A/R coating directly onto the detector has been proved on a band very similar to the short-wave band required for WIRE. Characterization of these 128- x 128-pixel arrays has also shown excellent response uniformity, response linearity over a wide dynamic range, and over 97 percent pixel operability.

4.0 FOCAL PLANE ARRAY MOUNTS

Previously, these 128- x 128-pixel arrays have been mounted in 68-pin, leadless chip carriers for testing and use in ground-based astronomy applications. The WIRE team felt this mount would likely be unsuitable for a rocket-launched satellite, so a new mount design was investigated. The new mount needed to meet the following requirements: be rugged enough mechanically to survive rocket launch, have excellent thermal transfer between the mount and the hybrid itself, be able to withstand repeated thermal cycling with no degradation, be able to monitor temperature variations and stability, and be able to isolate any stray background radiation from the active area of the detectors. It was also desired that the mount design isolate the output driver power from the hybrid.

The WIRE FPA mounts as designed have a strong heritage from the SPIRIT III mounts. Both have a thermal post of beryllium, both use a shrink-fit thermal connection, and both use polyamide/constantan tape cables to carry signals to the vacuum interface. In both designs the hybrid chip is bonded to a sapphire or alumina tab that is then bonded to the beryllium mounting post. In the SPIRIT III design, the tab is actually a ceramic multilayer circuit board. For the WIRE design, the circuit board is a flexible Kapton circuit, which is cut out to fit around the hybrid. The hybrid thus maintains excellent thermal contact to the beryllium heat sink without relying on any intermediate elements. The satellite chip is located some distance away from the hybrid; again, it has its own direct thermal path to the beryllium through either a silicon or sapphire tab. Figure 6 is a pictorial representation of the WIRE focal play array/mount assembly. Bear in mind that the SPIRIT III hybrid chip was actually 2.5 times longer than the WIRE hybrid chip design.

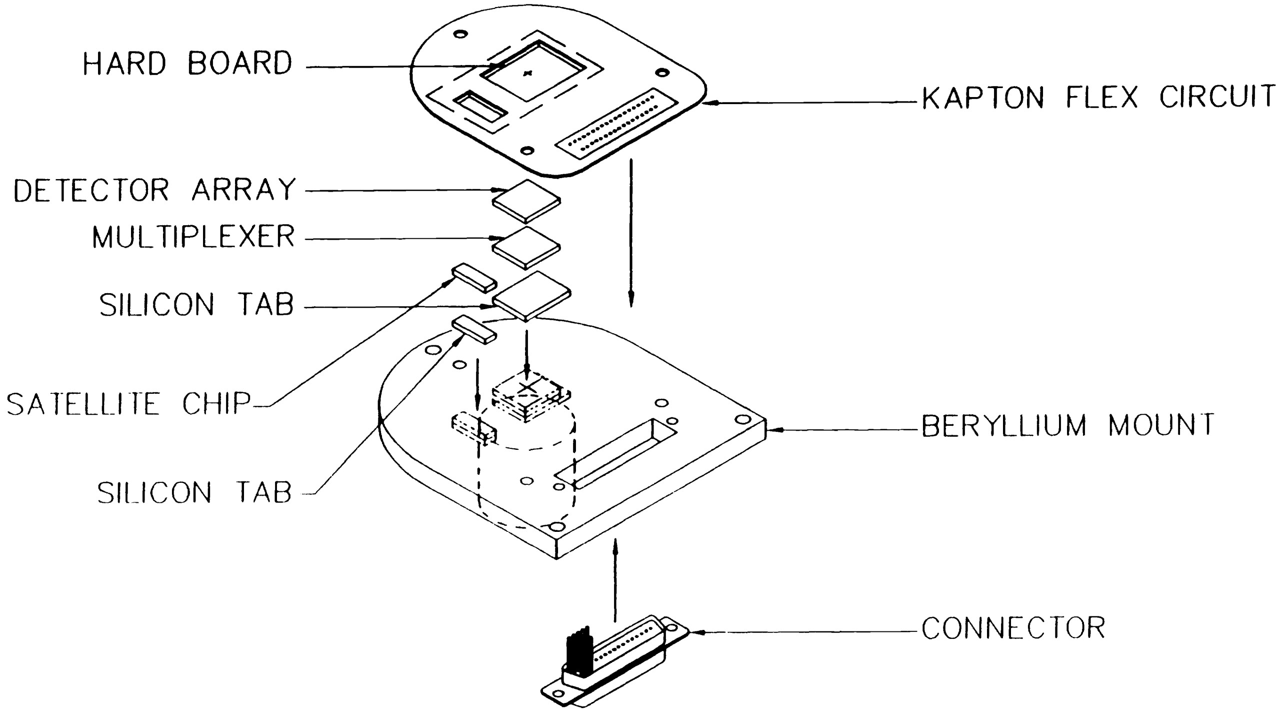

Figure 6. Pictorial concept of WIRE FPA/mount assembly showing beryllium heat sink, hybrid and satellite chip, and Kapton flexible circuit.

Two silicon diode temperature sensors will be attached to the beryllium and will be in close proximity to the hybrid chip to monitor temperature excursions. Numerous decoupling capacitor chips will also be mounted to the circuit board to reduce noise. Connections between the hybrid and satellite chips and the circuit board will be made by wire bonding. The plan is to use Stycast 2850 epoxy to bond the silicon/sapphire tabs and flexible circuit card to the beryllium and to bond the hybrid and satellite chips to the tabs.

When cooled from 293 Kelvin to 7 Kelvin, beryllium has a total contraction of 1,300 ppm; silicon has a total contraction of only 230 ppm. Sapphire—with an average thermal contraction of 630 ppm—makes an excellent intermediary material to buffer the differential thermal contractions. Thermal cycle tests have been run with two test tabs of the same size as the hybrid when epoxied to beryllium substrates. The test pieces have survived 50 thermal shock cycles between liquid nitrogen and room temperatures without any damage to either the tab materials or the Stycast bonds.

The Kapton flexible circuit card is very similar to flexible tape cables that have been used for at least a decade for similar focal plane arrays. However, there are fewer copper circuit layers in the flexible circuit card than in the previous ceramic multilayer circuit card. Three conductive layers are planned: the first layer will consist of wire bond pads and capacitor mounting pads, the second layer will be the interconnect layer, and the third layer will be a ground plane. There are cut-outs in the circuit board so it can fit around the hybrid and satellite chips and be mounted independently to the heat sink. There is a hard board attached to the Kapton circuit card in the area around the cut-outs to provide a good surface for epoxying the circuit board to the beryllium. This hard board will also provide a stiffener to facilitate wire bonding to the circuit board pads. Bonding of the Kapton circuit board to the beryllium will be done with a full-face glue surface. Board installation will be done at room temperatures, and the board will be slightly flexed to ensure that the initial differential contraction caused when it is cooled to 7.5 Kelvin leaves no residual stresses in the circuit card.

Electrical connections from the FPA to the outside world will be made using a tape cable that provides the best compromise between low electrical resistance and high thermal impedance. The conductors will be 0.001-in. thick by 0.005-in. wide constantan traces on 0.010-in. centers. These traces will be insulated by 0.001-in. thick Kapton layers with 0.0005-in. adhesive bonding. Around the conductive traces there will be a 0.0005-in. thick constantan shield with a 20-percent open that acts as an electromagnetic interference (EMI) shield. Another insulating layer of Kapton that is coated with a 1,000-Å thick layer of deposited gold will serve as a radiation shield. This cable will have heat stations for attaching thermally at the 7.5 Kelvin and 12 Kelvin cryogen tanks and also at the 130 Kelvin vapor-cooled radiation shield. This heat stationing should eliminate any heat from the warm outside shell (about 230 Kelvin during flight) from being conducted down the tape cable. For a 34-in. long cable, the impedance in each trace is about 131 ohms. With the capacitances expected in the various circuit elements, this provides an RC time constant of 1.3 microseconds, which yields an electrical bandwidth of 122 KHz—about six times that required for the selected readout times of the FPAs.

A total thermal budget of 5 milliwatts has been allocated for the FPAs and will include the active power dissipation in the hybrid and satellite chips and the parasitic heat leak from the tape cables. Eight milliwatts have been allocated for thermal conduction down the tape cables to the 12 Kelvin heat station at the secondary tank. Extensive thermal cycling as well as shock and vibration qualification is planned for the first FPA/mount assemblies off the formal production line.

Our FPA procurement strategy is to have Rockwell focus solely on the focal plane assemblies. In several past programs, the FPA vendor has also been contracted to supply all of the associated signal-conditioning electronics. For WIRE, the vendor's primary responsibility will be the FPAs; the only electronics Rockwell has been asked to deliver are the signal-conditioning and drive electronics interfacing directly to the arrays themselves. These electronics—shown in figure 7 below in block-diagram form—will consist of the analog gain and offset, bias derivation, and clock signal level-shifting electronics. Note that optical isolators and a careful grounding scheme have been incorporated into the design to eliminate any interference problems between the two sets of electronics. The A-to-D conversion and timing generation will be provided by SDL/USU. SDL/USU also plans to provide all the necessary electronics for qualification testing so that testing done at Rockwell will use the same set of electronics as used in flight. Finally, having SDL/USU produce a majority of the electronics gives added flexibility for quick adaptation to changing program needs.

After the initial hybrid screening has been completed by Rockwell, the hybrids will be mounted in lots of three to six in their full-flight configuration, i.e., beryllium heat sinks, isolating tabs, and Kapton circuit cards, and will be tested. Once testing verifies that an optimum detector lot has been identified, that all circuitry, tape cables, etc., are functioning, and that the assembly is mechanically and thermally rugged, Rockwell will fabricate enough assemblies to yield four flight-qualified arrays—two for each band and as many as four spares for testing at Cornell. Rockwell will also supply Cornell with a full set of the FPA electronics, and SDL/USU will provide Cornell with any associated system electronics so that the university can carry out its testing using the same configuration and circuitry that will be used in flight.

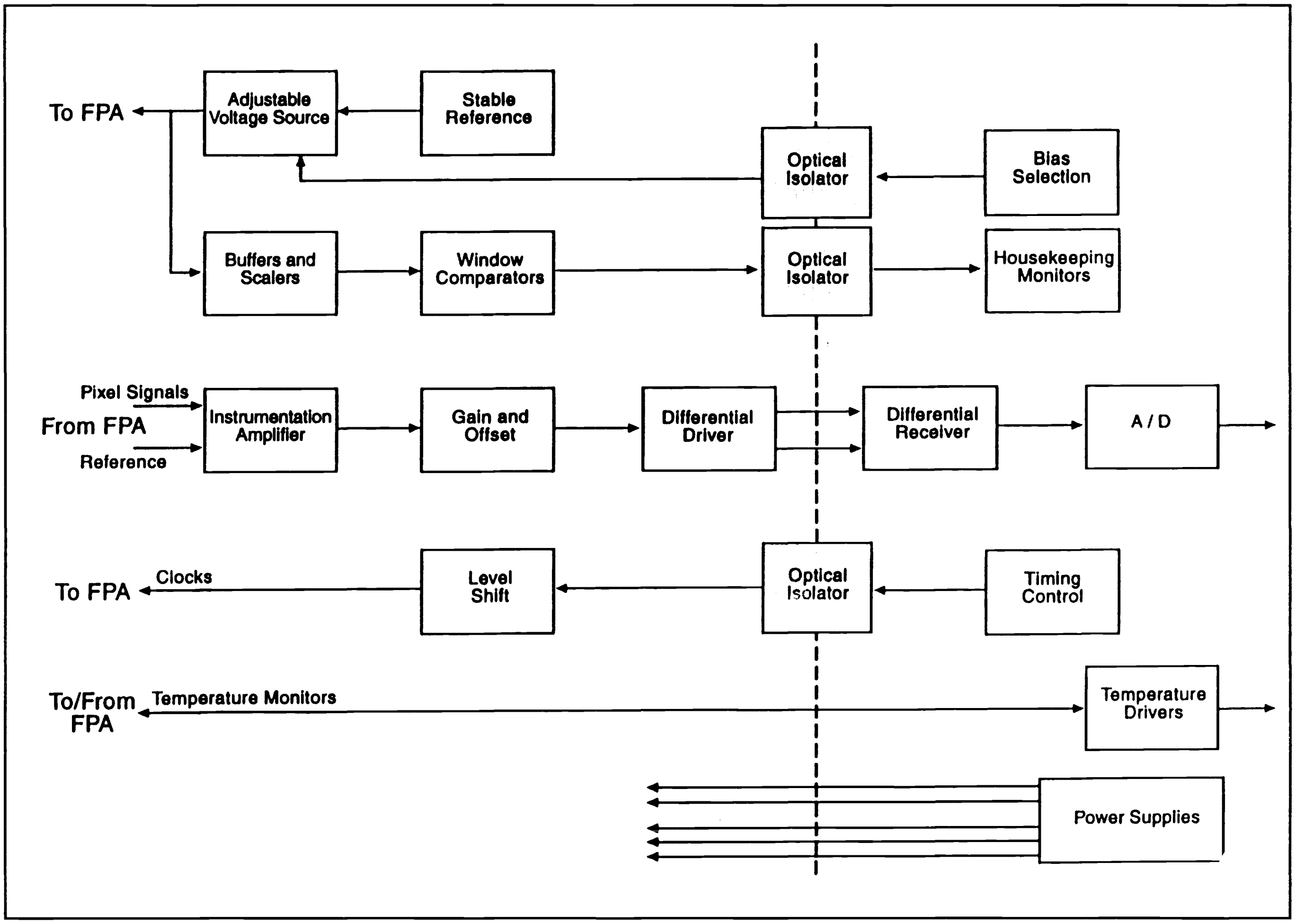

Figure 7. Block diagram of FPA driving and signal-conditioning electronics. Elements to the left of the dotted line are supplied by the FPA vendor.

5.0 WIRE ELECTRONICS

The cooled portion of the WIRE instrument is shown inside the block at the left-hand side of the diagram in figure 8 below. The spacecraft interface elements are shown to the right of the heavy line labeled "bus interface." The remainder of the elements shown in the block diagram are located between the two—inside the WIRE electronics box, or WEBox. The box labeled "FPA electronics" has been already been discussed and is shown in figure 7 above. The FPA electronics interact directly with the FPA, receiving such commands as "bias" and "frame rate" from the SDL/USU electronics. Another block diagram, this one showing in more detail how these commands are generated in the SDL/USU electronics, is shown in figure 9, also below. This system uses selectable look-up tables to give great flexibility in the clocking of the FPAs and allows experimentation even as late as into the characterization phase to ensure that the optimum clocking scheme is available for flight.

To speed up readout time, each FPA is designed to have four output channels. These output signals are passed from the FPA through instrumentation amplifiers and passed through gain and offset blocks through differential drivers to the differential receivers and the A-to-D converters located in the SDL/USU electronics. The outputs from the A-to-D converters are multiplexed together before being fed into the coadd circuitry. The signals from the FPAs will be coadded in the WIRE electronics for a nominal "frame time" of 64 seconds (as long as WIRE is staring at the same region of space). All the electronics—both FPA-related and others—will be located in the one electronics box but will be separated and shielded from each other to minimize interaction and noise generation.

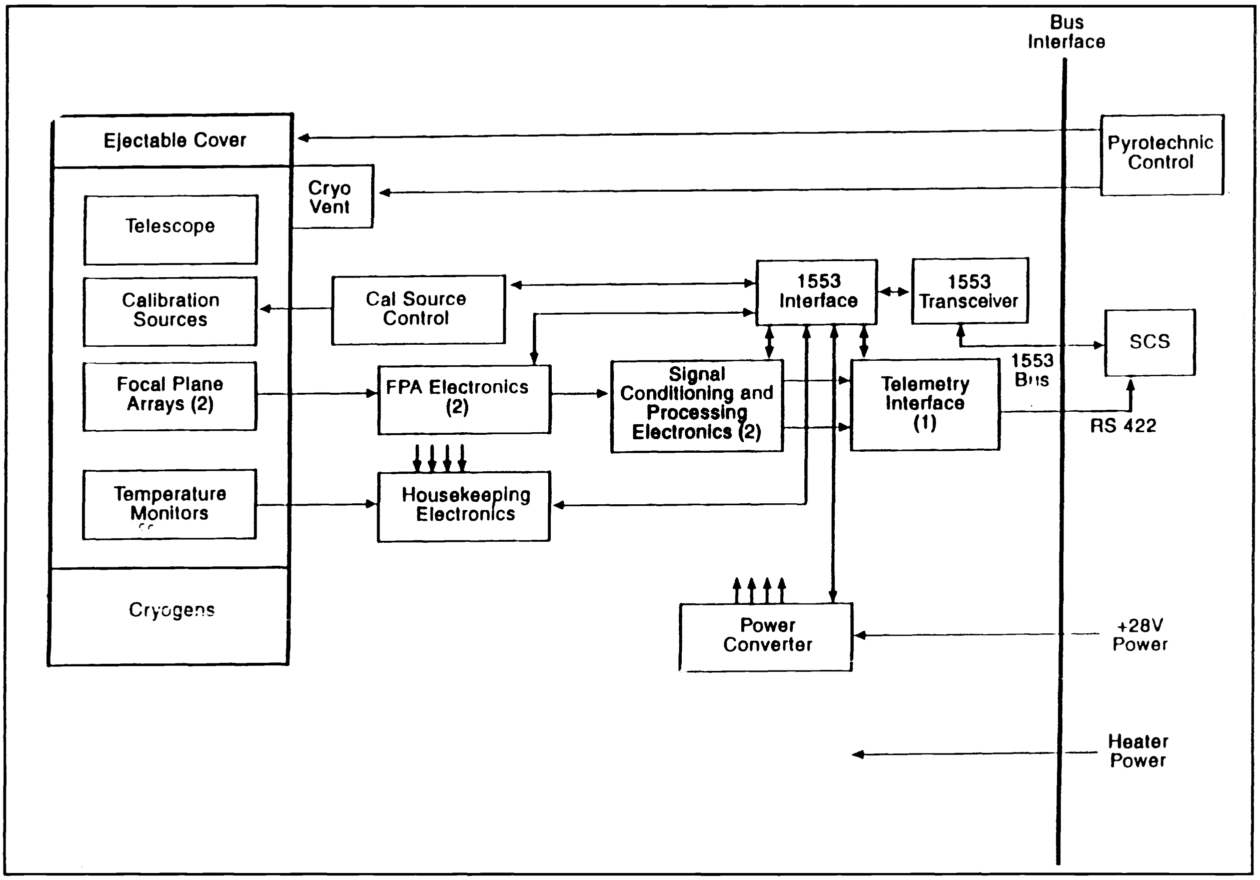

Figure 8. Block diagram of WIRE instrument.

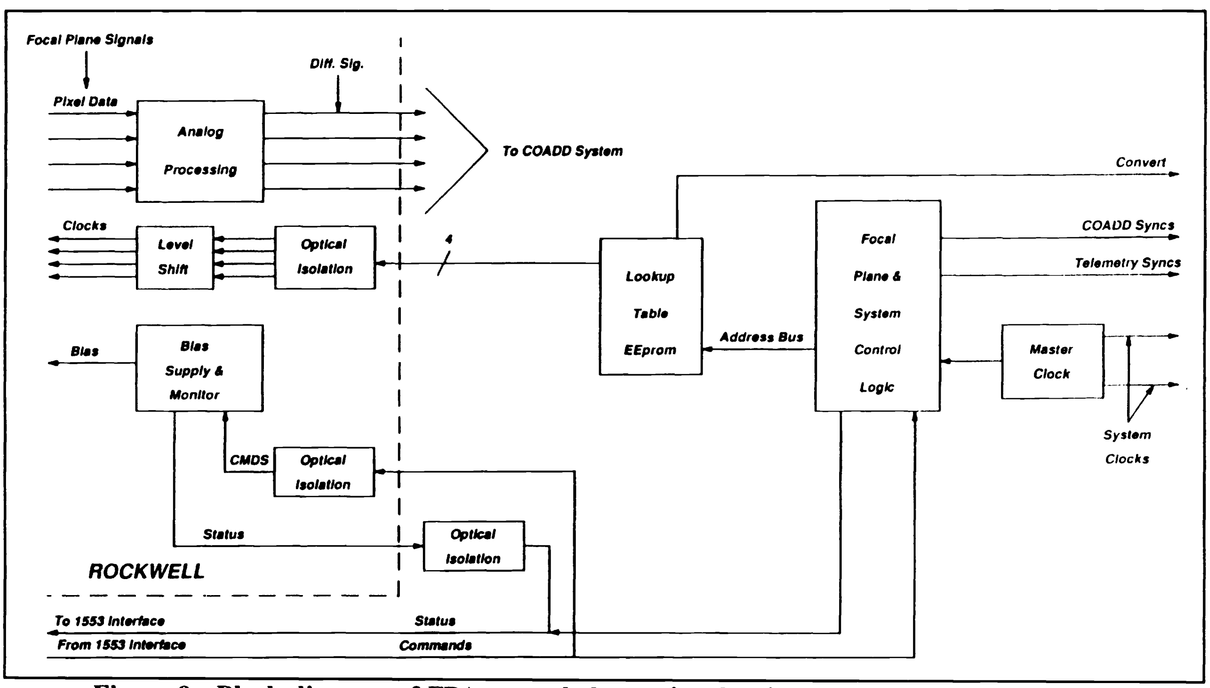

Figure 9. Block diagram of FPA control electronics showing clock-generating elements.

6.0 CONCLUSION

Recent advances in Si:As FPA technology have made possible an elegantly simple instrument of the small explorer class to measure far-infrared radiation from starburst galaxies. The extremely low dark current and read noise in the FPAs make possible the coaddition of signals over the staring period of each orbit. The high-spatial resolution of the 128- x 128-pixel FPAs also allows images from different orbits to be registered, which means that additional signal coaddition can be done over very long periods of time. This yields unprecedented sensitivity and long look-back times. The high-performance FPAs are complemented by a compact, low-weight, on-axis telescope that uses diamond-turned mirrors to achieve diffraction-limited performance in both wavelength bands.

7.0 ACKNOWLEDGMENTS

SDL/USU's definition-phase work on the WIRE program has been carried out under subcontract 959786 with the California Institute of Technology Jet Propulsion Laboratory (JPL), under NASA Contract NAS7-918. SDL/USU is the prime instrument contractor; the focal plane arrays will be provided by Rockwell International Corporation. SDL/USU is pleased to team with JPL and work with Dr. Perry Hacking, the principal investigator, and Dr. Helene Schember, the program manager. Many other individuals have also made significant contributions to the WIRE program. Of particular mention are Dr. A. J. Steed, D. A. Burt, Dr. T. Herter, Dr. M. G. Stapelbroek, D. H. Seib, W. A. Armstrong, W. A. Gibbons, M. Roosta, S. H. Schick, and G. Wickwar.

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