Multispectral thermal imager (MTI) payload overview

R. Rex Kay^a, Steven C. Bender^b, Tammy D. Henson^a, Donald A. Byrd^c, Jeffrey L. Rienstra^a, Max L. Decker^a, N. Glenn Rackley^a, Paul J. Claassen^a, Ronald E. Kidner^a, Richard B. Taplin^a, David M. Bullington^a, Kevin D. Marbach^a, Chris E. Lanes^a, C. Little^b, Barham W. Smith^b, Brian C. Brock^a, and Paul G. Weber^b

^a Sandia National Laboratories*, Albuquerque, New Mexico 87185

^b Los Alamos National Laboratory, Los Alamos, NM 87545

^c Silicon Valley Group, Tinsley Division, 3900 Lakeside Dr., Richmond, CA., 94806

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ABSTRACT

MTI is a comprehensive research and development project that includes up-front modeling and analysis, satellite system design, fabrication, assembly and testing, on-orbit operations, and experimentation and data analysis. The satellite is designed to collect radiometrically calibrated, medium resolution imagery in 15 spectral bands ranging from 0.45 to 10.70 μm . The payload portion of the satellite includes the imaging system components, associated electronics boxes, and payload support structure. The imaging system includes a three-mirror anastigmatic off-axis telescope, a single cryogenically cooled focal plane assembly, a mechanical cooler, and an onboard calibration system. Payload electronic subsystems include image digitizers, real-time image compressors, a solid state recorder, calibration source drivers, and cooler temperature and vibration controllers. The payload support structure mechanically integrates all payload components and provides a simple four point interface to the spacecraft bus. All payload components have been fabricated and tested, and integrated.

Keywords: multispectral, infrared, visible, imager, radiometry, calibration, image compression, satellite

1. INTRODUCTION

This paper will introduce readers to the Department of Energy's (DOE's) Multispectral Thermal Imager (MTI) project with emphasis on the satellite imaging subsystems. MTI is a Research and Development (R&D) project, sponsored by DOE's Office of Nonproliferation and National Security and executed by Sandia National Laboratories, Los Alamos National Laboratory and Savannah River Technology Center. Other government participants include the Air Force Research Laboratory, the National Institute of Standards and Technology and the Air Force Space Test Program, which is funding and managing the launch. Major industry participants include Ball Aerospace, Raytheon Optical Systems, Raytheon Infrared Center of Excellence and TRW. Over fifty government, private and academic organizations are involved in the development. The satellite is scheduled to launch in February 2000 from Vandenberg Air Force Base on an Orbital Sciences Corporation Taurus Launch Vehicle.

DOE's primary objective for MTI is to develop and evaluate advanced multispectral and thermal imaging, image processing and associated technologies for detecting and characterizing nuclear and other Weapons of Mass Destruction (WMD) facilities. To achieve this objective, the project will launch and operate a satellite with an advanced multispectral pushbroom imaging payload, capable of imaging sites in 15 spectral bands, ranging from visible to long-wave infrared, with accurate radiometry.

During its three year mission, the MTI satellite will periodically record images of participating government, industrial and natural sites in fifteen visible and infrared spectral bands. These bands are selected to provide a broad range of data related to potential proliferant facilities, including surface temperatures, materials, water quality, and vegetation stress¹. To achieve thermometric and reflectance accuracies required by the mission, the system also includes bands selected to collect simultaneous information on the intervening atmosphere, such as column water vapor, aerosol content and subvisual clouds. The combination of spectral bands, accurate radiometry and good spatial resolution make MTI unique among current and

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planned space-based imaging systems. Participating sites will be instrumented to record ground truth data to permit investigators to compare, analyze and validate satellite data against ground truth.

In addition to the primary DOE sensor, the MTI satellite will carry a High energy X-Ray Spectrometer (HXRS) sponsored by the National Oceanic Atmospheric Administration (NOAA), with additional funding from the Astronomical Institute Academy of Sciences of the Czech Republic, and built by Space Devices, Ltd. of the Czech Republic. HXRS is designed to record a rare species of solar flare associated with high-energy proton storms known to damage satellites and potentially endanger astronauts. From HXRS, NOAA hopes to obtain data needed to design a system capable of forecasting such storms.

2. SYSTEM OVERVIEW

The MTI satellite will be in a circular, sun synchronous orbit, initially injected at 575 kilometers. Ascending equatorial crossings will occur at 1:00 PM spacecraft local time, descending crossings at 1:00AM. This provides for the collection of both daytime and nighttime imagery. Figure 1 shows a typical ground track for one day. A site is considered to be available for imaging if it is up to ± 20 degrees off nadir in the cross-track direction (approximately ± 200 kilometers on the ground). The satellite ground track precesses each day, allowing a given sight to be available for imaging every seven days, on average. The satellite has no propulsion system so the orbit will decay as the mission progresses, and the orbit plane will drift about one hour over three years.

Figure 1. Typical one day ground track, ± 200 kilometers, for MTI's orbit.

The satellite will autonomously collect, compress and store up to six 2-look, 15-band, 12×12 kilometer images per day. A 2-look image sequence is defined as an image of a site taken at nadir, followed by a second image of the same site taken at up to 55 degrees off nadir, as shown in Figure 3. The 2-look sequence provides for imaging a single site through two different atmospheric depths. The second image will be used in post collection processing to aid in separating the radiometric contributions of the atmosphere from those of the ground scene.

During each of two daily passes over the ground station, located in Albuquerque, New Mexico, the system will downlink image data and uplink a new target list. Raw image data will be forwarded to the Data Processing and Analysis Center, located in Los Alamos, New Mexico, where it will be processed and converted to standard data products and distributed to various experimenters.

2.1. Major system performance goals

Spectral Bands. Visible, shortwave infrared (SWIR), midwave infrared (MWIR), and longwave infrared (LWIR), per Table 1.

Ground Sample Distance (GSD). Per Table 1.

Absolute Radiometric Accuracy. 3 % in the reflective bands and 1% in the thermal emissive bands for targets greater than 100 meters in extent, per Table 1.

Noise Equivalent Radiance (NER). Per Table 1. Measured NER's for Bands J through N are also shown. Measured data for the visible and near infrared bands are not yet available.

Field of View. 12 x 12 km (nominal).

Field of Regard. ± 200 km from ground track.

Geographic Coverage. All CONUS sites covered.

Pointing Accuracy. ± 0.25 degrees.

Temporal coverage. Average site revisit time is 7 days at 1300 or 0100 hours ± 1 hour.

View angles. 2-looks, one near nadir and another at 50-55 degrees off nadir.

Imaging capacity. Six 2-look, 15-band images per day.

Mission duration. 3 year goal.

Band	Wavelength Range (microns)	GSD (meters)	Radiometric Accuracy (percent)	Noise Equivalent Radiance (NER) (Watt/cm ² /sr/μm)	NER (Measured) (Watt/cm ² /sr/μm)
A	0.45 - 0.52	5	3	4.4E-5	-
B	0.52 - 0.60	5	3	2.8E-5	-
C	0.62 - 0.68	5	3	3.2E-5	-
D	0.76 - 0.86	5	3	2.3E-5	-
E	0.86 - 0.90	20	3	3.0E-5	-
F	0.91 - 0.97	20	3	6.0E-6	-
G	0.99 - 1.04	20	3	1.7E-5	-
H	1.36 - 1.39	20	3	5.2E-7	-
I	1.55 - 1.75	20	3	4.8E-6	-
J	3.50 - 4.10	20	1	1.3E-7	7.4E-8
K	4.87 - 5.07	20	1	6.6E-7	1.8E-7
L	8.00 - 8.40	20	1	4.4E-6	4.4E-7
M	8.40 - 8.85	20	1	3.2E-6	4.9E-7
N	10.20 - 10.70	20	1	3.9E-6	6.7E-7
O	2.08 - 2.35	20	3	1.2E-6	-

Table 1. Spectral bands and band dependent specifications.

3. SATELLITE OVERVIEW

The satellite is shown in Figure 2. It weighs 614 kilograms and is roughly cylindrical in shape, 135 cm in diameter and 260 cm in length. The satellite normally flies with the back of its solar paddles toward the sun (payload is anti-sun pointing), and the optical system aperture door closed. This orientation is referred to as standby mode. To image, it executes required attitude maneuvers to point the imaging payload at the target by slewing the entire satellite, opens the aperture door, records the image, then returns to its standby mode orientation. In addition to terrestrial imaging, the satellite will be maneuvered to image celestial objects for vicarious calibration purposes. Standby mode allows for a stable thermal environment for the payload between images, as well as providing an optimum orientation for battery charging.

The satellite consists of a spacecraft bus and imaging payload. The bus, built by an integrated Ball Aerospace/Sandia team, provides the payload with a 3-axis stabilized platform, 315 watts of average power, radio frequency communications, and command and data handling. The bus contains no on-board propulsion; all maneuvers are executed using reaction wheels.

Figure 2. MTI Satellite during system test.

Figure 3. Two-look maneuver concept.

The payload, shown as a block diagram in Figure 4, includes a telescope, cryogenically cooled focal plane with 15 linear spectral-sensitive detector arrays, built-in calibration sources and mechanisms, supporting structure, and associated readout and control electronics (not shown). The telescope images scenes onto the focal plane arrays. Data required to form images in 15 spectral bands is recorded as the satellite ground track motion scans the image over the 15 linear detector arrays in "pushbroom" fashion. The individual pixels provide spatial resolution in the cross-track direction and temporally consecutive readouts of the detector provide spatial resolution in the along-track direction. The cross-track field is approximately 12 km.

Figure 4. Payload block diagram.

The payload consists of an Optics Assembly with a 36 cm off-axis telescope, calibration sources built into a double-hinged door and internal calibration wheel, a Focal Plane Assembly (dewar) with linear detector arrays at the focal plane that operates at 75 K, and control and readout electronics.

3.1. Optical Assembly

The Optical Assembly (OA)², built by Raytheon Optical Systems, includes the telescope structure, optics, calibration sources built into the double hinged aperture door and internal wheel assembly, focus mechanism, various actuators and other mechanisms, and numerous thermistors and heaters for temperature control.

The OA design features a 36 cm aperture, three-mirror off-axis anastigmatic (TMA), f/3.5 telescope design, housed in a composite structure for dimensional stability. The unobscured design offers near diffraction limited performance in the infrared bands². It also eliminates scattering and thermal emissions from structures that would be within the field of view of the focal plane arrays in an on-axis design.

Figure 5 A shows the back of the primary and tertiary mirrors. The bottom photograph (B) is a front view showing the aperture end of the telescope. This view shows the double hinged aperture door in the closed position. The door is normally closed, and will be opened only during imaging and certain calibration operations as described in the Calibration section. It is secured during launch by a hot wax actuated launch lock. Figure 8B also shows the aluminum can that houses the focus mechanism, which precisely adjusts the position of the secondary mirror (the smallest of the three mirrors). The opening in the top right of the OA is the Focal Plane Assembly mount.

Figure 5. Optical Assembly.

The top photograph (A) shows the rear of the OA with a cover removed revealing light-weighted primary (right) and tertiary (left) mirrors. The bottom photograph (B) shows the front of the OA with the aperture door closed.

Figure 6. Optical Assembly (top) during mating with the payload structure.

3.1.1. Thermal Design

A necessary condition for radiometric accuracy is radiometric stability. Radiometric stability in the thermal infrared wavelength bands is in part achieved by ensuring all components which can contribute to the radiation incident on the focal plane are stable in temperature. The TMA design provides a real, accessible exit pupil which allows 100% cold shielding of direct illumination of the focal plane by the warm OA structure. The exit pupil and cold shield are thermally tied to the 75 kelvin FPA and are an integral part of the focal plane package. The exit pupil operates at approximately 117 Kelvin. The mirrors are the only components outside of the cold shield which can directly radiate into the focal plane. The payload

structure radiation must be scattered into the focal plane to contribute, so its effect on the total signal are relatively small. In order to maximize thermal stability, the entire OA, including its internal components, are temperature stabilized at approximately 273 Kelvin by Kapton film heaters and thermostatic controllers applied to the exterior surfaces of the structure, as shown in Figure 5 A and B.

The entire OA is wrapped with multi-layer insulation to thermally isolate it from the outer aluminum payload structure as shown in Figure 6. The OA is suspended in the payload structure by a kinematic mounting system at three points. A pair of kinematic links ties each of these points to the payload structure. This system constrains the OA's six degrees of freedom without inducing mechanical stress from the primary structure, it suppresses launch vibration coupled into the OA for frequencies above 45 Hz and it minimizes heat transfer between the OA and the payload structure.

The temperature of OA components are measured so their effects on the total signal reported by the focal plane can be quantified. The temperature measurements system has several groups of thermistors in which measurement precision has been optimized for their particular application. The specifications are shown in Table 2.

Table 2 also lists the operating temperature of various components, temperature stability requirements, and the actual temperature deviations observed during system test. The measured temperature deviations shown are short term (approximately 30 minutes) measurements. The focal plane temperature must also be very stable over the time frame of a calibration and image sequence (about 2 minutes) because changes in dark current in the focal plane detector material can be mistakenly interpreted as a change in incident radiation. Temperature stability of the focal plane is discussed further in Section 3.3.

Component	Nominal Temperature (K)	Source Stability to end of life (+/-K)	Short Term Stability (+/-K) Requirement	Short Term Stability (peak to peak measured)	Measurement Precision (+/-K)
Focal Plane	75	N/A	0.05	0.04	0.007
Cold Shield	118	N/A	2.0	N/A	None
Dewar Window	273	N/A	1.5	N/A	None
Optical Structure	273	N/A	5	2	0.015
Aperture Blackbody	274.5	0.2	0.12	0.02	0.006
Quick Look Blackbodies	283.2 260.2	0.24	0.11	0.013	0.004

Table 2. Component temperature stability requirements and measurements.

3.2. Focal Plane Assembly

Figure 8 is a cutaway line drawing of the Focal Plane Assembly (FPA)³, built by Santa Barbara Research Center. At its heart are six sensor chip assemblies (SCAs) mounted on three motherboards as shown in Figure 7. Each SCA consists of photosensitive detector material and a silicon readout integrated circuit (ROIC). For bands A-D, the detectors and ROIC are implemented as a monolithic structure. For bands E-O, the photosensitive material is bump bonded to the ROIC. The ROIC provides pre-amplifiers for each pixel and circuitry for serializing pixel outputs onto analog output lines.

The three motherboards connect to cryogenic cables, which interface to warm connectors. Each SCA pair contains a set of three types of linear arrays capable of detecting the required range of wavelengths:

- Monolithic silicon PIN diodes for visible and near infrared (VIS/NIR) bands A-D (12.4 μm pitch)
- Backside illuminated photovoltaic indium antimonide (InSb) for NIR/SWIR/MWIR bands E-K and O (49.6 μm pitch).
- Backside illuminated photovoltaic mercury cadmium telluride (HgCdTe) for LWIR bands L-N (49.6 μm pitch)

The SCA's, including the PIN diodes, are designed to operate at 75 K. This single focal plane design alleviates the need for a beam splitter to separate visible and infrared spectral components.

Interference filters mounted in a bezel over the SCAs, shown in the bottom photograph of Figure 7, precisely select wavelength bands. The motherboards with sensor chip assemblies and filter bezel are mounted in an optically baffled and cold shielded housing. The FPA is mounted into the OA with its window placed just ahead of the telescope's exit pupil. The cold shield aperture is aligned precisely with the telescope's exit pupil, prohibiting thermal emissions from the OA structure from directly illuminating focal plane detectors. The barium fluoride window passes the broad range of wavelengths detected by MTI. The FPA housing mates to a vacuum housing surrounding the cryogenic cooler cold head by way of a flexible bellows. This housing allows the volume surrounding the cold head, focal plane, and cold shield to be evacuated, and hence cooled to 75 K, with the remainder of the OA and payload at ambient laboratory temperature and pressure. This greatly simplifies the task of testing and aligning the infrared portions of the focal plane compared with a system in which the entire payload must be placed in a vacuum chamber before the infrared detectors can be cooled.

3.3. Cryogenic Cooler

The pulse-tube cryogenic cooler, built by TRW, is shown in Figure 9A. It maintains the focal plane at 75 K and the FPA cold shield at 117 K. The unit is capable of producing greater than 3 watts of cooling capacity at 65 K (at its cold tip). The actual heat load was measured as approximately 2.5 Watts. Only 0.517 Watts results from focal plane electrical power dissipation; the remainder results from thermal loading, primarily on the cold shield. An opposing cylinder design and control electronics provide both active vibration and temperature control.

Platinum resistance thermometers (PRT's) are used to measure the temperature of the cooler cold tip and also the focal plane temperature. A 9.5 Kelvin thermal gradient exists across the cold strap and the bolted interfaces between the strap, focal plane, and cold tip. Either PRT can be chosen as a control sensor for temperature stabilization. The PRT mounted to the focal plane is the preferred sensor for maximizing FPA temperature stability based on empirical data. The control loop is implemented in software resident in the Cooler Control Electronics (CCE). The temperature is varied by modulating the stroke of the compressors.

In addition to modulating compressor stroke, a second method for controlling FPA temperature is designed into the system. Three 60 milliwatt resistance heaters and temperature sensing diodes are mounted to each of the sensor chip assemblies. Power to the heaters can be modulated by means of a control loop which uses the temperature sensing diodes as feedback. The controller can operate in closed loop or open loop, constant power, setpoint mode. It was found empirically that the

stroke modulation method provides adequate FPA stability: operation of the heaters is not necessary. Measured peak to peak FPA temperature variation is less than 0.04 Kelvin over a 30 minute interval which includes the load variations induced by sequencing through the Quick Look Calibration Sources (QLCS), described in further detail in Section 3.4.

During operation, the cooler generates approximately 70 Watts of waste heat in the compressors. This heat is conducted to two radiator panels through two sets of variable conductance heat pipes attached to heat reject surfaces on the compressors. The conductance of the heatpipes is modulated by an active control loop which maintains the heat reject temperature at -7 ± 2 degrees Celsius. Maintaining a constant reject temperature also contributes to focal plane temperature stability because the cooler efficiency is not constant with varying reject temperature.

Figure 9B shows the cooler mounted to the payload. Thermal connection is made through the flexible cold strap shown in Figure 9C, which is connected to the back of the FPA via the three threaded holes shown in Figure 9D. The bellows shown between the cooler and back of the FPA in Figure 9B permits the volume surrounding the cooler and focal plane to be evacuated, while maintaining a soft interface. The combination of the bellows and flexible cold strap isolates the FPA from any movement between the payload structure (where the cooler is hard mounted) and the OA (where the FPA is hard mounted). It also reduces any residual vibration that might be transmitted to the FPA from the cooler on orbit.

Line of sight jitter was measured during focus testing of the imaging system to be on the order of 1 high resolution pixel (10 microradians) peak to peak ². Line of sight jitter was measured with the cooler operating at nominal stroke and with the cooler off. No discernable difference in the data was observed between the cooler on and cooler off cases; therefore, the jitter contribution from the cooler was not measurable in the presence of external disturbances in the laboratory.

Figure 9. Photographs of the Cryogenic Cooler and its interfaces to the Focal Plane and Payload Structure.

3.4. Calibration

The radiometric accuracy goals DOE has established for MTI, over wavelengths ranging from 0.45 to 10.70 μm , are fundamental to the mission objective. To meet this challenge, MTI's calibration strategy is based on accurately calibrating the sensor prior to launch and then maintaining calibration on orbit.

To minimize uncertainties due to thermal effects, the thermal subsystem monitors and controls both focal plane and OA temperatures. The focal plane is actively maintained at 75 K by controlling cooler stroke and heat pipe conductance. OA temperature is maintained at a near uniform 275 K by heater tapes in 42 zones using 90 temperature monitors.

The built-in calibration system employs stable sources, the sun, and cold space to maintain long-term calibration. The basic strategy is to use the MTI sensor itself as a transfer radiometer between the NIST-traceable ground-based calibration system and the onboard calibration sources. Once this transfer has been established, on-orbit operations will employ the onboard calibration hardware to continually verify it and monitor any changes. Built-in calibration components are shown in Figure 15. Two sources are built into the aperture door. As shown in Figure 16, the door is double hinged to allow two different

Figure 15. Optics and built-in calibration components.

Figure 16. Double hinged Door.
The double hinged floods the instrument with black body radiation or diffused sunlight for full aperture calibration.

surfaces to fill the telescope field of view, providing end-to-end calibration of the imaging system. When the door is closed (it is kept closed except when imaging), it presents the dark surface (coated with Chemglaze Z306) to the system. This is a temperature-controlled blackbody radiator for full-aperture calibration of the infrared channels.

Still referring to Figure 16, the other side of the double hinged door is painted white (Z93P paint). With the aperture door partially opened to 45 degrees and the second hinge extended, the satellite can be oriented to reflect sunlight, flooding the aperture with a diffused source for calibrating the visible through SWIR channels. Referring back to Figure 15, a solar ratioing radiometer near the aperture opposite the door hinge is used to monitor the door's reflectance by measuring both direct and panel reflected sunlight in five spectral bands corresponding to imager bands A through E.

Again referring to Figure 15, another set of calibration sources is mounted inside the telescope in a wheel assembly. These sources are used to obtain a quick look at drift and 1/f effects just prior to and following imaging. The assembly mounts into the side of the OA structure, just in front of the FPA housing, and is referred to as the Quick Look Calibration Source (QLCS). A photograph of the unit is shown in Figure 17. The very large cutout in the wheel is positioned in front of the focal plane when the system is imaging. Four calibration sources are positioned around the wheel at 72 degree intervals. The first

source position contains a narcissus, or retro, mirror, which is viewed by the focal plane when the system is not imaging to minimize the thermal load on the cryogenic cooler and to provide a cold reference for all subsequent calibration source and scene images. The next two positions contain identical blackbody calibration sources. One source is operated at 280 Kelvin, the other at 360 Kelvin. The blackbody radiator areas are small compared to the cold stop aperture. Some of this area factor is corrected for by the use of zinc selenide lenses which form a magnified image of the radiators on the focal plane. The fourth position contains a fold mirror which reflects the image of the exit port of an integrating sphere which is illuminated using one of two on-board 6 Watt quartz-tungsten-halogen (QTH) lamps.

Redundant stepper motors, harmonic drives, and clutches are used to rotate the calibration wheel assembly between its various sources. Any QLCS source can be positioned in front of the FPA cold shield to within ± 0.18 mm accuracy.

Figure 17. QLCS Assembly on test stand. The open position is shown at 9 o'clock, the retro mirror at 12 o'clock and one of the blackbodies at 3 o'clock. The projection assembly to the right houses the integrating sphere and QTH lamps

3.5. Readout and Control Electronics

The design of the support electronics are driven in large part by the calibration and imaging scenarios. While imaging, the nominal nadir ground sample time in the along track direction is 715 microseconds for bands A-D ($12.4 \mu\text{m}$ pitch detectors) and 2.86 milliseconds for bands E-O ($49.6 \mu\text{m}$ pitch detectors). Integration times for all bands are variable up to 12 microseconds less than the pixel readout rate. A single detector array scans a 12 km image in about 1.7 seconds. The detector arrays are staggered in the along-track direction, so the system images a given point on the ground at slightly different times for each of the spectral bands. The focal plane readout electronics allows individual programming of start and stop times for each band in each SCA so that the data sets from each band will completely overlap. A single 12 x 12 kilometer image requires about 4.5 seconds. Whether or not data from a particular band is collected and saved is programmable to optimize image storage space. For example, solar reflectance bands need not be saved for nighttime images.

High-speed analog-to-digital converters digitize outputs of each pixel with 12-bit resolution. Typical noise levels from the focal plane readout and off-chip electronics are about 0.6 to 0.8 counts RMS. When imaging in all bands, the focal plane readout electronics generate 266 megabits/second of data for real-time compression and storage. Data is transferred by means of a 380 megabit/second capacity serial data link from the focal plane readout electronics to the image compression hardware.

The image compression hardware utilizes the Universal Source Encoder for Science data (USES) chip developed by the Institute of Advanced Microelectronics at the University of New Mexico. It implements the Rice coding algorithms⁴ for lossless compression. The chip is operated in external predictor mode which encodes the difference between a pixel's present value and a predictor. Additional memory storage hardware was added to the compression system to allow storing of the previous pixel values in each band for use as the predictor. The USES chip would otherwise use a nearest spatial neighbor for prediction; however, this method leads to less efficient compression because of fixed pattern noise present in the image data. A compressed 2-look image set in all 15 bands is approximately 500 megabits in size, assuming a 2.5:1 compression ratio.

The payload image and state-of-health data is stored and transmitted using the Consultative Committee for Space Data Systems (CCSDS)⁵ standard for spacecraft data. The standard defines a packetized data structure, which allows for efficient use of downlink bandwidth for data sources with widely varying data rates, and Reed-Soloman error detection and correction encoding.

The various optical and mechanical imaging and calibration components and mechanisms are controlled and read out by five electronic packages.

Focal Plane Readout—controls focal plane readout, digitizes analog image data and passes it to the payload recorder interface

Payload Recorder Interface—compresses and formats mission data in real-time and writes it into a solid state recorder (Mass Storage Unit)

Mass Storage Unit (built by Odetics)—stores 4.1 gigabits of mission and housekeeping data between ground station passes

Telescope Calibration and Control Assembly—controls the optical assembly telescope and built-in calibration mechanisms and sources, and acquires OA and calibrator temperature measurements. Temperature measurement absolute accuracy is dominated by calibration knowledge of the thermistors, about 0.05 Kelvin. Measurement precision is shown in Table 2.

Cooler Control Electronics Assembly (built by TRW)—controls the cryogenic cooler

4. RADIOMETRIC STABILITY

The payload assembly has completed a five month calibration process at Los Alamos National Laboratory. Much of this data is presently undergoing analysis with absolute calibration results to be published at a later date. Preliminary analysis of radiometric stability for the thermal infrared bands has been completed. Table 3 shows data collected for bands J through N against the on board aperture blackbody (ABB) and the high and low temperature QLCS sources (HTBB and LTBB). An image of 30 scans in each band was collected while the retro mirror was placed in front of the FPA, followed by a 30 scan image while viewing each of the ADA, LTBB, and HTBB. Data is shown for pixel 113 (an arbitrary choice) in each SCA and band J through N. The average signal from the retro mirror has been subtracted from the average signal from the source and the resulting analog to digital (A/D) converter counts are shown in the columns labeled "Average". This data collection procedure was performed nine times during the five month calibration activity. The standard deviations (Sdev) for these nine collections are also shown in both A/D counts and percent of average signal. It can be seen that most standard deviations are less than 0.2 percent.

			SCA 1			SCA 2			SCA 3	
Band	Source (K)	Average (Counts)	Sdev (Counts)	Sdev (%)	Average (Counts)	Sdev (Counts)	Sdev (%)	Average (Counts)	Sdev (Counts)	Sdev (%)
J	ABB (274.5)	455.579	0.970	0.213	535.739	1.284	0.240	456.161	0.956	0.210
K	ABB	1296.624	1.430	0.110	1433.085	1.178	0.082	1299.042	1.269	0.098
L	ABB	875.47	0.912	0.104	935.233	1.782	0.191	1104.973	1.478	0.134
M	ABB	824.627	0.874	0.106	819.973	0.909	0.111	892.264	1.597	0.179
N	ABB	554.664	0.951	0.171	852.282	0.992	0.116	887.091	1.689	0.190
J	LTBB (283.2)	304.741	0.809	0.265	346.215	1.337	0.386	301.346	0.708	0.235
K	LTBB	915.5	1.814	0.198	1013.711	1.843	0.182	898.313	2.318	0.258
L	LTBB	606.664	0.567	0.093	699.017	2.689	0.385	768.946	0.791	0.103
M	LTBB	583.003	0.556	0.095	623.233	0.609	0.098	663.474	1.270	0.191
N	LTBB	400.323	0.291	0.073	635.326	0.573	0.090	640.159	0.642	0.100
J	HTBB (360.2)	2566.145	1.300	0.051	2782.528	1.849	0.066	2517.428	1.794	0.071
K	HTBB	2392.589	2.028	0.085	2514.361	1.688	0.067	2359.556	2.484	0.105
L	HTBB	2024.356	1.847	0.091	2281.744	3.301	0.145	2448.089	1.396	0.057
M	HTBB	1808.928	1.721	0.095	1902.045	1.415	0.074	2014	2.138	0.106
N	HTBB	973.305	0.794	0.082	1561.172	1.387	0.089	1551.822	0.719	0.046

Table 3. Radiometric Stability Data for Bands J through N, pixel 113.

5. SUMMARY

In summary, MTI is a comprehensive R&D project, executed by an integrated multi-laboratory team of DOE scientists, engineers and analysts, with major support from other government agencies, academia and private industry. It is a complex project that includes up-front modeling and analysis, system design, fabrication, assembly and testing, on-orbit operations, experimentation and data analysis. The project will bring together and advance a number of state-of-the-art, but relatively mature, technologies and methodologies in anticipation of an early and rich R&D payoff.

Although MTI is specifically aimed at advancing technologies and collecting data needed to build more capable operational systems for monitoring WMD treaties and other agreements, the technology is rich with other important national security and civilian applications. Non-DOE experimenters in over forty government organizations will investigate these applications and currently participant through the MTI Users Group.

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