EDUCATION, SCIENCE AND TRAINING

SENATE LEGISLATION COMMITTEE - QUESTIONS ON NOTICE
2006-2007 ADDITIONAL ESTIMATES HEARING

Outcome: CSIRO
Output Group: CSIRO

DEST Question No. E947_07

Senator Carr asked on 14 February 2007, EWRE Hansard page 48.

Question:

Patent Application

Senator CARR— Are you able to table that correspondence? Given that you are going to send it all off to the US Patent Office, surely you can provide it to the Australian Senate.

Dr Steele—Some of the correspondence relates to the patent and whether the patent is in good standing. It is that correspondence which we will be tabling to the US PTO.

Dr Steele— I do not have complete copies of that here at the moment. If the committee wants to ask for it, I would need to provide it on a later occasion.

Senator CARR—Take it that the committee has asked for the correspondence to be provided.
Answer:

CSIRO has provided the following response.

Patent Application

CSIRO intends to provide to the USPTO, in relation to the national phase applications for the "APPARATUS FOR REMOTE MONITORING OF A FIELD OF VIEW", PCT/AU2004/001340 and "AN INFRARED DETECTION APPARATUS" PCT/AU2004/001338, copies of the executed assignment forms that were previously executed by Drs Prata and Bernardo and a jointly authored letter by Drs Prata and Bernardo dated 6 June 2006, together with copies of the attachments to that letter which are: two non-executed 267-97 Assignment forms; an undated article entitled *Infrared Gas Imaging: A new industrial solution for live imaging and concentration measurement of gases* by CEDIP Infrared Systems; an article entitled *Infrared cloud imager deployment at the north slope of Alaska during early 2002* by J.A Shaw et al; and an undated, three page extract from a PhD thesis. A copy of that correspondence is attached.

At the time of providing this correspondence to the USPTO, CSIRO will give consideration to whether there are other documents that CSIRO believes it would also be appropriate to provide.

Dr Cirilo Bernardo
89 Cowper St.
Dickson
ACT 2601
Australia

Dr Fred Prata
116 Humphries Road
Mt Eliza
Victoria 3930
Australia

267-97

6 June 2006

Mr Brian Thomas
Commercial Manager
CSIRO Atmospheric Research
Private Bag 1
Aspendale, Victoria 3195, Australia

Dear Brian

Re: Patent assignment documents

We have received the USPO forms and read what is required of us in order to sign them. Unfortunately we are unable to sign the forms for the following reasons:

1. We aware of prior art and of disclosures made by Tenix on this invention. CSIRO has documents on file which disclose a similar system developed by FL-IR Systems and revealed to CSIRO under NDA prior to 2003.
2. As previously indicated to CSIRO managers both verbally and formally in writing on many occasions, starting with an email to Michael Edwards in September 2003, we do not think the statements made in the patent applications are truthful or correct. Indeed we are able to demonstrate that there are numerous errors in the patents which must surely invalidate most, if not all of, the claims. Furthermore, we do not believe CSIRO, Tenix or anyone else can reproduce the results shown in the patent applications, because the raw data and data analyses contain these errors. These errors resulted from pressure to provide patentable technology without sufficient time allowed to test and validate the science. We were told at the time that we would have the opportunity to correct these errors, but no such opportunity has been given.

With regard to (1) above on prior art, we simply ask you to read the attached documents which refer to a product by CEDIP/Bertin (France) and a research instrument (the "Infrared Cloud Imager"–US) which has been in operation since early 2002. Both of these devices use uncooled microbolometer IR cameras to image the atmosphere, clouds and plumes. The US device discloses a calibration system (detailed in a PhD thesis which is publicly available) and is obviously the same as the calibration system described in the CSIRO patents (see extract from the PhD attached). The French system is a mature product and not only utilises the same IR camera technology as that used by G-bIRD but also uses the same IR filters, and presumably correct processing algorithms. The Bodkin patents clearly represent relevant prior art and we can see nothing in the CSIRO patents that is not obvious from the Bodkin patents. We also point out that there is a document on CSIRO files titled "Cloud Monitoring Sensor" which was disclosed to CSIRO under NDA by FLIR systems in 1998 or 1999 (we do not recall the exact date). The document on CSIRO files contained the words "commercially sensitive". This document (and perhaps others) would have been found had the IP diligence recommended by the Invetech Review been undertaken by CSIRO.

On the matter of public disclosures, we draw your attention to a PPT presentation made at a public meeting in Boulder, Colorado in July 2003. The PPT (Tenix and CSIRO have copies) discloses the G-bIRD system and results and was presented by a representative of Georgia Tech at the request of Matt Simmons of Tenix. We do not believe a CSIRO staff member or Tenix employee were present at the meeting, but several people who attended the meeting were able to describe the G-bIRD system to us. Tenix (Matt Simmons) also disclosed the G-bIRD system and results at a meeting in Toulouse in October 2003. The CSIRO presentation was withdrawn on the basis that the results were incorrect.

With regard to (2), we remind you of the numerous emails to you and other senior CSIRO managers in which we clearly indicated our dissatisfaction with the patents and suggested, again on many occasions, that the R&D required to make the inventive step had not yet been done. We also indicated to you that neither Fred Prata nor Cirilo Bernardo had been given the opportunity by CSIRO/Tenix to take those inventive steps. You will have on file numerous unapproved proposals from CSIRO to Tenix that show that the majority of the science was not complete at the time of filing the provisionals and to the best of our knowledge this R&D has not been completed since.

As of 6 June neither of us had received copies of the patent applications and any ammendments, although I uderstand something has been sent since. We have not had sufficient opportunity to read and review these documents as required in form "RULE 63 (37 C.F.R. 1.63)".

In summary, as named inventors in these patent applications, we are strongly objecting to their validity.

Your sincerely

(Dr Fred Prata)

(Dr Cirilo Bernardo)

cc. Nixon & Vanderhye, Griffith Hack

267-97

ASSIGNMENT OF PATENT APPLICATION

(Inventors) **Cirilo BERNARDO**
Alfredo Jose PRATA

In consideration of the sum of one dollar ($1.00) and other good and valuable considerations paid to each of the undersigned, the undersigned agree(s) to assign, and hereby does assign, transfer and set over to

(Assignee) COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION.
(Address) of Limestone Avenue, Campbell, Australia ACT 2612
(hereinafter designated as the Assignee) the undersigned's entire right, title and interest for the United States, its territories, dependencies and possessions, and for the country of
(Other Countries) in the invention, and all application(s) for patent and any Letters Patent which may be granted therefor, known as
(Title) A INFRARED DETECTION APPARATUS (Case No. 267-97)
for which the undersigned has (have) executed on even date herewith an application for patent in the United States of America or, if not on even date, then has executed on or has already filed in U.S. appln. Serial No. , filed on March 29, 2006.
The undersigned acknowledges an obligation of assignment of this invention to said assignee at the time the invention was made.

The undersigned agree(s) to execute all papers and documents necessary in connection with the application or any interference which may be declared and any continuing or divisional applications thereof and also to execute separate assignments in connection with such applications as the Assignee may deem necessary or expedient and further to perform any act which may be necessary in connection with claims or provisions of the International Convention for Protection of Industrial Property or similar agreements.

The undersigned agree(s) to perform all affirmative acts which may be necessary to obtain a grant of a valid United States patent to the Assignee.

The undersigned hereby authorize(s) and request(s) the Commissioner of Patents to issue any and all Letters Patent of the United States resulting from said application or any division or divisions or continuing applications thereof to the said Assignee, as Assignee of the entire interest, and hereby covenants that he has (they have) full right to convey the entire interest herein assigned, and that he has (they have) not executed and will not execute, any agreement in conflict herewith.

The undersigned hereby grant(s) the firm of NIXON & VANDERHYE P.C. the power to insert on this assignment any further identification which may be necessary or desirable in order to comply with the rules of the United States Patent Office for recordation of this document. It is understood and agreed that ASSIGNEE'S attorneys Nixon & Vanderhye P.C. have represented only ASSIGNEE and will continue to represent only ASSIGNEE with respect to this invention.

In witness whereof, executed by the undersigned on the date(s) opposite the undersigned signature(s).

Date 19/6/2006 Signature of Inventor (Cirilo BERNARDO

Date 9/6/6 Signature of inventor (Alfredo Jose PRATA

Patent application and amendments not seen by me.

1057764

267-97
NGM:MJL:FP23601

Nixon & Vanderhye P.C. (10/99)
(Domestic Non-Assigned/Foreign) Page 1

RULE 63 (37 C.F.R. 1.63)
INVENTORS DECLARATION FOR PATENT APPLICATION
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

As a below named inventor, I hereby declare that my residence, mailing address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:
A INFRARED DETECTION APPARATUS

the specification of which (check applicable box(es)):
[ ] is attached hereto
[X] was filed on March 29, 2006 as U.S. Application Serial No. (Atty. Dkt. No. 267-97)
[X] was filed as PCT International application No. PCT/AU2004/001338 on 29 September 2004
and (if applicable to U.S. or PCT application) was amended on March 29, 2006

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose to the Patent Office all information known to me to be material to patentability as defined in 37 C.F.R. 1.56. I hereby claim foreign priority benefits under 35 U.S.C. 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed or, if no priority is claimed, before the filing date of this application:

Priority Foreign Application(s):

Application Number	Country	Day/Month/Year Filed
2003905316	AU	29 September 2003
2004900214	AU	16 January 2004

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below.

Application Number	Day/Month/Year Filed

I hereby claim the benefit under 35 U.S.C. 120/365 of all prior United States and PCT international applications listed above or below:

Prior U.S./PCT Application(s):

Application Serial No.	Day/Month/Year Filed	Status: patented pending, abandoned
PCT/AU2004/001338	29 September 2004	

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon. And on behalf of the owner(s) hereof, I hereby appoint Nixon & Vanderhye P.C., telephone number 703-816-4000 (to whom all communications are to be directed) and the attorneys of: **Customer Number 23117**, individually and collectively owner's/owners' attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith and with the resulting patent. I also authorize Nixon & Vanderhye to add or delete attorneys from that Customer Number, and to act and rely solely on instructions directly communicated from the person, assignee, attorney, firm, or other organization sending instructions to Nixon & Vanderhye on behalf of the owner(s).

1. Inventor's Signature: [signature] Date: 19/6/2006
Inventor: Cirilo (first) MI BERNARDO (last) United States (citizenship)
Residence: (city) Dickson (state/country) Australia
Mailing Address: 89 Cowper St, Dickson, Australia
(Zip Code) ACT 2602

2. Inventor's Signature: UNABLE TO SIGN – See attached reasons Date: 9/6/06
Inventor: Alfredo (first) Jose MI PRATA (last) Australia (citizenship)
Residence: (city) Mount Eliza (state/country) Australia
Mailing Address: 116 Humphries Road, Mount Eliza, Australia
(Zip Code) VIC 3930

[ ] ***See attached sheet(s) for additional inventor(s) information!!***

1057761

267-98

ASSIGNMENT OF PATENT APPLICATION

(Inventors) Cirilo BERNARDO
Alfredo Jose PRATA

In consideration of the sum of one dollar ($1.00) and other good and valuable considerations paid to each of the undersigned, the undersigned agree(s) to assign, and hereby does assign, transfer and set over to

(Assignee) Commonwealth Scientific and Industrial Research Organisation
(Address) of Limestone Avenue, Campbell, Australian Capital Territory, Australia 2612
(hereinafter designated as the Assignee) the undersigned's entire right, title and interest for the United States, its territories, dependencies and possessions, and for the country of
(Other Countries) in the invention, and all application(s) for patent and any Letters Patent which may be granted therefor, known as
(Title) APPARATUS FOR REMOTE MONITORING OF A FIELD OF VIEW (Case No. 267-98)
for which the undersigned has (have) executed on even date herewith an application for patent in the United States of America or, if not on even date, then has executed on or has already filed in
U.S. appln. Serial No. , filed on March 29, 2006.
The undersigned acknowledges an obligation of assignment of this invention to said assignee at the time the invention was made.

The undersigned agree(s) to execute all papers and documents necessary in connection with the application or any interference which may be declared and any continuing or divisional applications thereof and also to execute separate assignments in connection with such applications as the Assignee may deem necessary or expedient and further to perform any act which may be necessary in connection with claims or provisions of the International Convention for Protection of Industrial Property or similar agreements.

The undersigned agree(s) to perform all affirmative acts which may be necessary to obtain a grant of a valid United States patent to the Assignee.

The undersigned hereby authorize(s) and request(s) the Commissioner of Patents to issue any and all Letters Patent of the United States resulting from said application or any division or divisions or continuing applications thereof to the said Assignee, as Assignee of the entire interest, and hereby covenants that he has (they have) full right to convey the entire interest herein assigned, and that he has (they have) not executed and will not execute, any agreement in conflict herewith.

The undersigned hereby grant(s) the firm of NIXON & VANDERHYE P.C. the power to insert on this assignment any further identification which may be necessary or desirable in order to comply with the rules of the United States Patent Office for recordation of this document. It is understood and agreed that ASSIGNEE'S attorneys Nixon & Vanderhye P.C. have represented only ASSIGNEE and will continue to represent only ASSIGNEE with respect to this invention.

In witness whereof, executed by the undersigned on the date(s) opposite the undersigned signature(s).

Date 19/6/2006 Signature of Inventor (____________
Cirilo BERNARDO

Date 9/6/6 Signature of inventor (____________
Alfredo Jose PRATA

Patent application not seen by me, nor any amendments.

1057757

267-98
NGM:MJL:FP23599

Nixon & Vanderhye P.C. (10/99)
(Domestic Non-Assigned/Foreign) Page 1

RULE 63 (37 C.F.R. 1.63)
INVENTORS DECLARATION FOR PATENT APPLICATION
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

As a below named inventor, I hereby declare that my residence, mailing address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: APPARATUS FOR REMOTE MONITORING OF A FIELD OF VIEW

the specification of which (check applicable box(es)):
[ ] is attached hereto
[X] was filed on March 29, 2006 as U.S. Application Serial No. (Atty. Dkt. No. 267-98)
[X] was filed as PCT International application No. PCT/AU2004/001340 on 29 September 2004
and (if applicable to U.S. or PCT application) was amended on 29 March 2006

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose to the Patent Office all information known to me to be material to patentability as defined in 37 C.F.R. 1.56. I hereby claim foreign priority benefits under 35 U.S.C. 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed or, if no priority is claimed, before the filing date of this application:

Priority Foreign Application(s):

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I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below.

Application Number	Day/Month/Year Filed

I hereby claim the benefit under 35 U.S.C. 120/365 of all prior United States and PCT international applications listed above or below:

Prior U.S./PCT Application(s): Application Serial No.	Day/Month/Year Filed	Status: patented pending, abandoned
PCT/AU2004/001340	29 September 2004	

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon. And on behalf of the owner(s) hereof, I hereby appoint Nixon & Vanderhye P.C., telephone number 703-816-4000 (to whom all communications are to be directed) and the attorneys of: **Customer Number 23117**, individually and collectively owner's/owners' attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith and with the resulting patent. I also authorize Nixon & Vanderhye to add or delete attorneys from that Customer Number, and to act and rely solely on instructions directly communicated from the person, assignee, attorney, firm, or other organization sending instructions to Nixon & Vanderhye on behalf of the owner(s).

1. Inventor's Signature: [signature] Date: 19/6/2006
Inventor: Cirilo (first) MI BERNARDO (last) Australia (citizenship)
Residence: (city) Dickson (state/country) Australia
Mailing Address: 89 Cowper St, Dickson, Australia
(Zip Code) ACT 2602

2. Inventor's Signature: UNABLE TO SIGN - see attached reasons Date: 9/6/6
Inventor: Alfredo (first) Jose MI PRATA (last) Australia (citizenship)
Residence: (city) Mount Eliza VIC (state/country) Australia
Mailing Address: 116 Humphries Road, Mount Eliza VIC, Australia
(Zip Code) 3930

1057755

Infrared Gas Imaging. A new industrial solution for live imaging and concentration measurement of gases.

Infrared gas detection is a well-developed measurement technology, used in many applications from pollution monitoring to explosion sensing. Whilst much of the infrared gas detection market is mature there has been for some time considerable demand for an affordable and robust technique that can follow and measure clouds of gas in an open atmosphere.

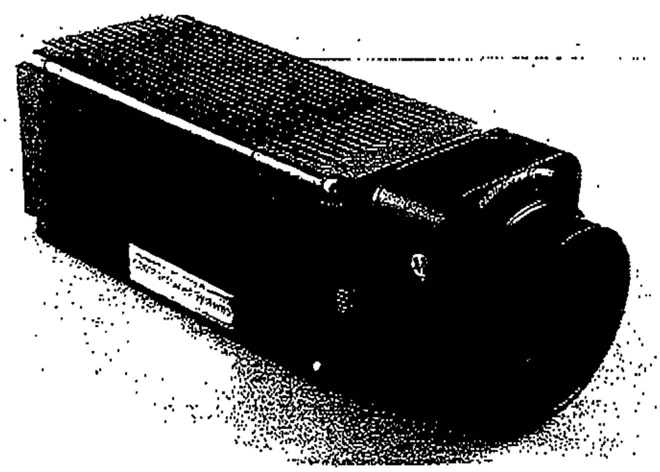

Figure 1. *Jade UC camera used in IR Gas Imaging system*

This article describes a new Infrared Gas Imaging product based upon the CEDIP Jade UC camera (**Figure 1**), that for the first time delivers the sensitivity, cost, reliability and lack of maintenance required of an industrial solution for live imaging and concentration measurement of gases. On an industrial scale the new product has been demonstrated to image clouds of gas, to follow their absorption and diffusion in the open atmosphere, and to measure their concentration. The applications for this new development are numerous. A major area of interest spurned by civil unrest around the world is in Homeland Security where governmental authorities want to address the potential risk of toxic gases introduced and spread by terrorist activists. Also there is strong demand from the oil and gas industry who are looking for techniques to monitor gases such as Methane or Butane during the production cycle and the risk of pollution arising from their storage.

The development and spread of industrial solutions for Infrared Gas Imaging has to date been limited by the cost and availability of imaging sensors that are sensitive enough in the spectral bands of interest to bring significantly added value compared to already existing technologies. Traditionally scientists have used high performance cooled IR cameras, especially those using MCT sensors in order to be sensitive in the 8-12µm spectral region. The cost of these MCT sensors has strongly limited the introduction of IR gas imaging into industrial applications. In addition the required maintenance and risk of failure of the MCT sensors cooling engine has also been a major limiting factor.

However the relatively recent emergence of reasonably priced, high performance microbolometer IR focal plane array detectors looks set to open the door to the industrial applications of Infrared Gas Imaging.. The industrial implementations of the technique also requires intensive image processing capabilities in order to limit the false alarm rate. False alarms have historically arisen due to object motion within the scene or where measurements are taken in bad weather conditions. The sensitivity achieved by new-generation microbolometer IR FPA detectors is now in the range of 50mK with F/1 lenses, which is better that what achieved with single MCT sensors only five years ago.

Detailed below are installed system results from the world's first commercially available IR gas imaging analyser using microbolometer FPA technology made by Bertin Technology (Aix en Provence, France). This innovative system is the result of more than ten years of research partially funded by defence budgets. The Bertin system uses a network of CEDIP Jade UC cameras equipped with a filter wheel with filters chosen to match the characteristic absorption wavelengths of the gas being surveyed.

The Bertin system has already shown great utility for surveillance of gases in high explosive risk areas, for instance in the vicinity of oil refineries and gas production facilities. The gases to be detected in these applications are typically

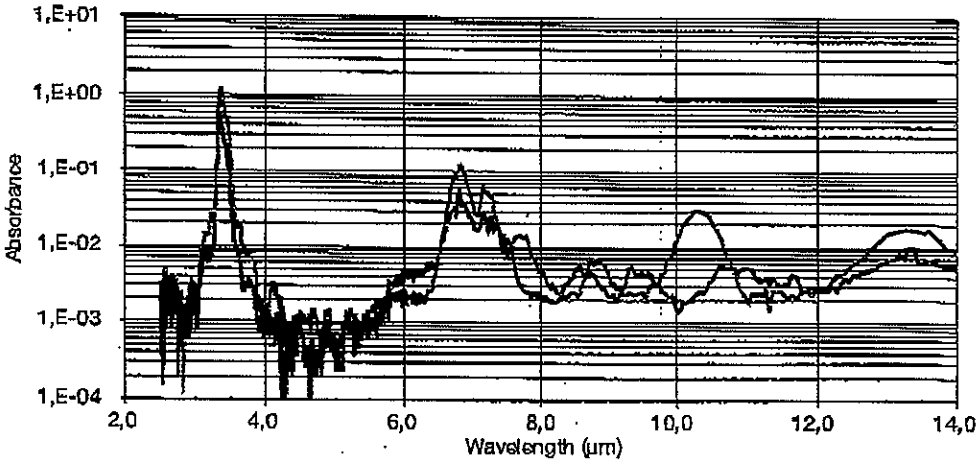

Figure 2. IR spectra of of Butane (C_4H_{10}) and Propane (C_3H_8).

butane (C_4H_{10}) and propane (C_3H_8). **Figure 2**, shows the spectral absorption curve for Butane (C_4H_{10}) and Propane (C_3H_8) gases, within the 2.0 to 14.0 micrometers range.

The chosen measurement peak for Butane is the strong absorption near 10.5µm that is positioned within the optimal spectral response of the microbolometer array. Other strong Butane spectral absorptions such as the peak near 7µm was not used as air is not transparent in this region and will by itself introduce strong signal attenuation. The spectral response of Propane is more difficult to detect since, as it can be seen, the gas does not absorb as strongly as Butane but rather offers two suitable smaller peaks centred near 8.5µm and 9.5µm.

Once detection wavelengths have been selected and set-up for the gas or gases to be surveyed, an industrial system must then demonstrate measurement robustness and reliability. To achieve this typically requires the implementation of sophisticated image processing techniques to both minimise the false alarm rate and enhance the signal-to-noise ratio. False alarms arise in Infrared Gas Imaging mainly due to motion of objects within the field of view. These objects are typically pedestrians, vehicles or animals. Dedicated spatial and temporal image filtering procedures have been developed and implemented by Bertin Technology to eliminate all these artefacts. The signal-to-noise enhancement features are based on image averaging techniques.

Figure 3 shows the Bertin system in place when observing a large industrial oil and gas site. The Infrared Gas Imaging system is linked to a computer which performs real time image processing and shows a new image of the gas cloud and its concentration every one second.

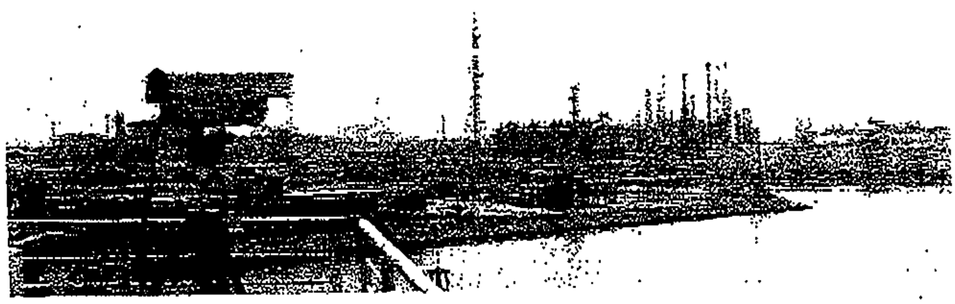

Figure 3. *The Bertin system shown observing an oil & gas production site.*

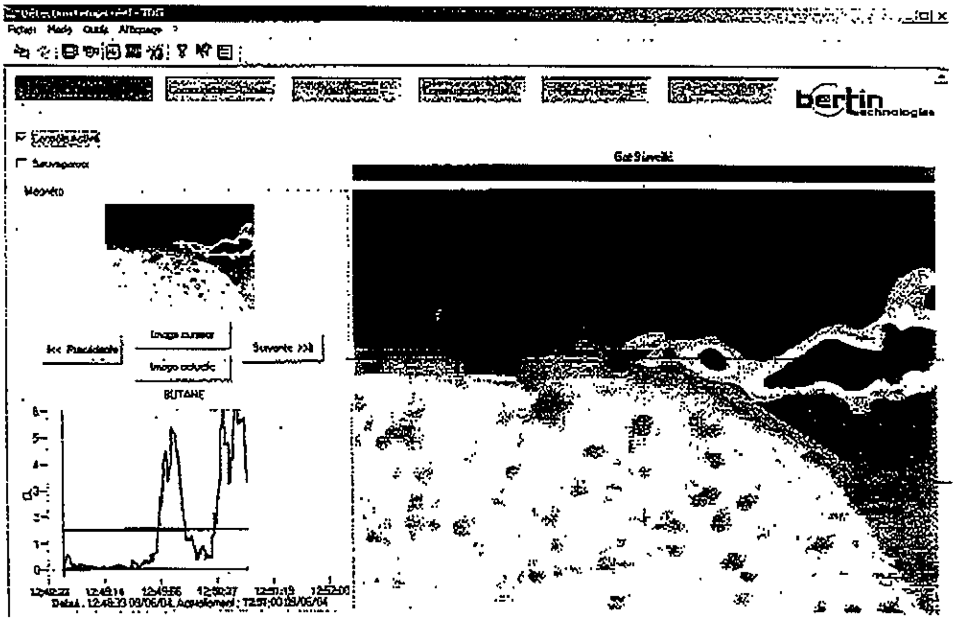

Figure 4. *Screen shot showing analysis of a Methane gas cloud.*

Figure 4 is a screen shot of the main computer screen where the image of the gas is illustrated in colour against the black and white background. The gas concentration in the cloud is also given.

Conclusions

Recent advances in microbolometer based IR focal plane array detector technology have opened the door to the realisation of the potential for Infrared Gas Imaging in a wide range of industrial and security applications.

Twelfth ARM Science Team Meeting Proceedings, St. Petersburg, Florida, April 8-12, 2002

Infrared Cloud Imager Deployment at the North Slope of Alaska During Early 2002

J. A. Shaw and B. Thurairajah
Department of Electrical and Computer Engineering
Montana State University
Bozeman, Montana

E. Edqvist
National Oceanic and Atmospheric Administration
Environmental Technology Laboratory
Boulder, Colorado

K. Mizutani
Communications Research Laboratory
Koganei, Tokyo, Japan

Introduction

Starting in February 2002, we deployed a new cloud-radiation sensor called the infrared cloud imager (ICI) at the North Slope of Alaska (NSA) site near Barrow, Alaska (71.32 N, 156.62 W). ICI records radiometrically calibrated images of the thermal infrared sky radiance in the 8μm to 14 μm wavelength band, from which spatial cloud statistics and spatially resolved cloud radiance can be determined.

Infrared Cloud Imager

The ICI is designed for simultaneously studying the spatial and radiative properties of clouds, especially in the Arctic atmosphere. The initial scientific objective in developing the ICI system was to provide spatial cloud statistics that could be used to complement the single-point-in-space but spectrally resolved sky emission data from a fourier transform infrared spectro-radiometer (FTIR). These two sensors are part of a large instrument suite deployed at Poker Flat Research Range near Fairbanks, Alaska, as part of a Japan and United States collaborative program to study the Arctic atmosphere (http://www2.crl.go.jp/dk/c216/index_e.html). Whereas visible-wavelength imagers use cloud texture or topology to distinguish cloud types, relying on scattered sunlight to illuminate the cloud (e.g. Buch et al. 1995), the ICI system identifies and classifies clouds directly from their emitted infrared radiance. Because the cloud emission signature is the same in day and night, ICI provides a significant advantage over visible-wavelength imagers in being able to produce a continuous day-night data stream with no change in sensitivity or cloud-detection algorithm.

One of the initial applications of the ICI system is to help determine how well cloud statistics from zenith-viewing, single-pixel instruments agree with cloud statistics from spatially resolving instruments.

Most currently operational cloud radars and lidars use a single vertically pointing beam and rely on advection of the cloud field over the instrument to build up space-time cloud statistics. This approach assumes ergodicity, or that ensemble, time, and space averages are equivalent. Taylor's hypothesis states that when the turbulence is small compared with the mean wind, temporal statistics at a single point in space can be used to infer spatial statistics. However, Sun and Thorne (2000) showed that Taylor's hypothesis usually does not hold for cirrus clouds and broken stratus, both cases of great importance in the Arctic. ICI was deployed during February – May 2002 at the NSA Atmospheric Radiation Measurement (ARM) site near Barrow, Alaska, with nearby cloud radar, cloud lidar, and other sensors to study how Arctic cloud statistics might vary between point-sensors and imaging sensors.

Long-term, unattended deployment of an infrared imager previously was impractical because of the need to regularly fill liquid nitrogen dewars or provide an alternate form of cooling the detector array to cryogenic temperatures. However, recently developed micro-bolometer detector arrays (Kruse 2001) provide an excellent solution to this problem because of their relatively high sensitivity without cryogenic cooling. The cost of cameras based on these detector arrays is falling steadily, so a network of these infrared cloud imagers is a practical goal for studying cloud variability throughout the world, at much higher spatial resolution and with improved radiometric contrast between cloud and background than can be achieved with satellites.

Infrared Cloud Imager Hardware

At the heart of the ICI system is a commercial infrared camera that uses an uncooled micro-bolometer detector array, technology only available to the military until recently. These detectors offer reasonably high sensitivity without the troubling need for liquid nitrogen cooling. Because these detector arrays are fabricated with technology similar to that used for standard silicon electronic chips, infrared cameras are beginning to be available at much lower cost.

The ICI system records radiometrically calibrated images of the sky with 320 × 240 pixels in the thermal infrared window band of 8 to 14 μm. The camera generates 30 frames per second, but the ICI only acquires a frame once every few minutes to avoid excessive redundancy. The original camera has a full-angle field of view of approximately 18° horizontal ×13.5° vertical, which is not as wide as is desirable for cloud measurements, but it allowed us to demonstrate the feasibility of this technique. Future versions of the ICI will use a wide-angle lens to achieve a wide field of view of up to 100°, which is nearly optimal for spatial cloud statistics (Long 2002).

As is illustrated in Figure1, the infrared camera looks horizontally at a beam-steering mirror (M) mounted on a stepper motor (SM), which rotates alternately between a blackbody (BB) calibration source and a sky port covered by a hatch that opens for image collection when a precipitation sensor (PS) shows no precipitation. The camera, blackbody, stepper motor, hatch, system diagnostics sensors, control electronics, and precipitation sensor all are mounted in the optics box which sits outside, controlled by a computer that sits in a nearby building or shelter (Figure 2 is a photograph of the optics box interior). The system is controlled via an internet connection, avoiding the need for an on-site operator. Each pixel of the calibrated sky images gives an absolute radiance or brightness temperature, from which clouds are identified and classified in categories such as clear, high, mid, and low.

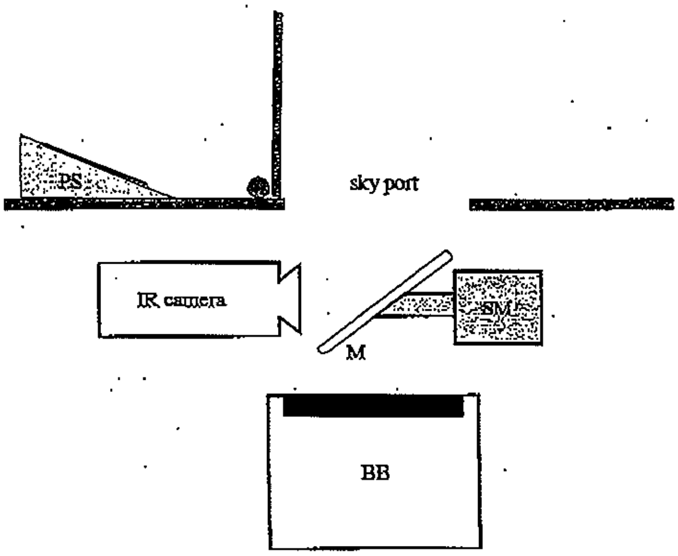

Figure 1. Illustration of the infrared camera looking horizontally at a beam-steering mirror (M) mounted on a stepper motor (SM).

Figure 2. Photograph of the optics box interior.

As is so often the case in passive remote sensing, making ICI work successfully is largely a problem in radiometric calibration. The calibration requirements for cloud identification and classification are far less demanding than those for most other atmospheric sensing applications [such as clear-sky absolute radiometry with FTIR spectro-radiometers, which require uncertainties < 1% (e.g., Shaw et al. 1999; Feltz et al. 1998). The ICI radiometric calibration has an uncertainty of approximately 2 to 6%, generally being largest at the cold clear-sky measurement range. The calibration relies on a linear fit between band-integrated radiance and voltage on each pixel, measured with the camera viewing a blackbody source at different temperatures. A least-squares fit provides a linear calibration equation of the form $L = G*V+C$, where L is the radiance measured in the camera's optical bandwidth, G is the radiometer gain (change in radiance for a given change in voltage), and C is an offset that describes the voltage output from the detector caused by thermal radiation within the instrument. The current ICI prototype uses only one blackbody calibration source, from which the offset, C, is updated for each image; the gain, G, is determined in a laboratory calibration and assumed to remain constant throughout the deployment. This assumption appears to remain sufficiently valid under typical conditions to allow the ICI to achieve the 2 to 6% calibration uncertainty that is good enough for cloud identification and classification. A second blackbody calibration source can be added if lower uncertainty is required in future deployments.

Radiometric Images from ICI

Figure 3 is a radiometrically calibrated image from the ICI, recorded with thin clouds overhead at the NSA site on March 19, 2002. The image was calibrated in radiance units [W/(m^2 sr μm)] and subsequently converted to band-averaged brightness temperature (K) for display. The display is color coded according to brightness temperature, ranging from −90°C at the bottom (dark blue) to +20°C at the top (dark red). The infrared emission signature makes the clouds stand out against the cold, clear background, although these thin clouds were not at all obvious to a visible-wavelength camera. The extremely low water vapor content of the wintertime Arctic atmosphere allows ICI to see an extraordinarily high radiometric contrast between the clear sky and thin clouds. In other locations with higher water vapor content, thin clouds will be more difficult to see with ICI (this will be the topic of future research at the ARM Southern Great Plains [SGP] site).

Figure 4 is a radiometrically calibrated image from ICI of scattered medium-level clouds with a mean band-average brightness temperature near −30°C. Especially on the left-hand side of the image, thin spots are visible as bluish areas in the image, indicating that ICI is seeing higher into the atmosphere through the cloud. When we process ICI images to derive spatial cloud statistics, each pixel is classified into a category of clear, high and thin, medium, or low clouds (or similar categorization, depending on the specific application) and cloud fraction is determined as the number of pixels containing clouds relative to the total number of pixels

Summary and Future Plans

The ICI system was deployed from February through May 2002 at the NSA site in Barrow, Alaska, performing satisfactorily in a wide range of conditions in a harsh environment. The prototype instrument achieves a radiometric uncertainty of approximately 2 to 6%, which is sufficient for cloud

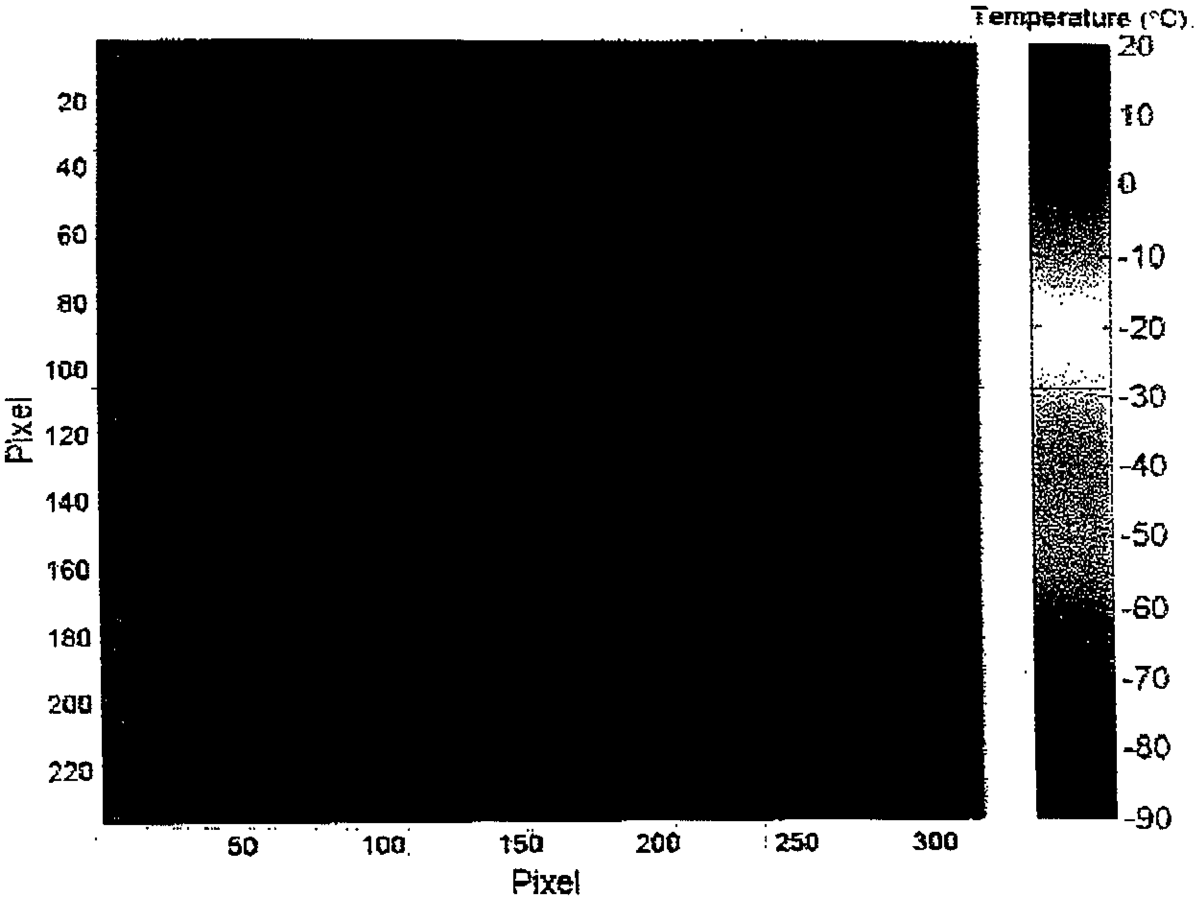

Figure 3. Radiometrically calibrated image from the ICI, recorded with thin clouds overhead at the NSA site on March 19, 2002.

identification and broad classification. The calibration uncertainty can be reduced with simple instrument modifications if it becomes necessary or desirable. The images from NSA demonstrate that the ICI has a high sensitivity to thin clouds in a cold, dry Arctic atmosphere. Future research will be conducted to quantify this capability in both Arctic and more humid atmospheres. The plans for the immediate future are to use the ICI data collected during this 2002 deployment to determine cloud statistics and to study the potential difference between cloud statistics measured with single-pixel and imaging sensors.

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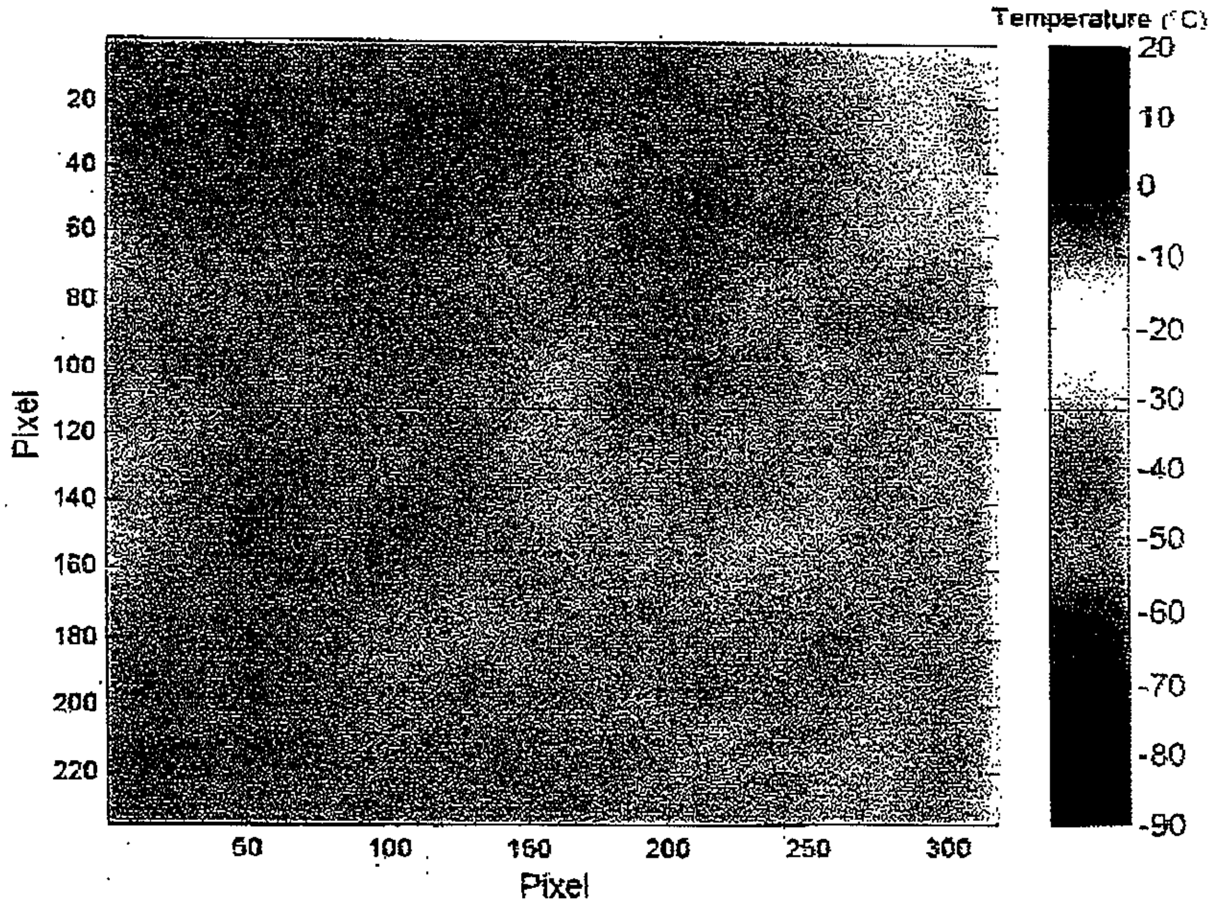

Figure 4. Radiometrically calibrated image from ICI of scattered medium-level clouds with a mean band-average brightness temperature near –30°C.

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Sun, C.-H., and L. R. Thorne, 2000: Inferring spatial cloud statistics from limited field-of-view, zenith observations. *In Proceedings of the Fifth Atmospheric Radiation Measurements (ARM) Science Team Meeting*, CONF-9503, pp. 331-334. U.S. Department of Energy, Washington, D.C. Available URL: (http://www.arm.gov/docs/documents/technical/conf_9503/76_95.pdf).

- After the mirror is rotated to face the blackbody it is always stepped back to compensate for overshoot.
- The blackbody images are taken for calibrating the sky image.
- The hatch is opened or closed only after verifying the sensor voltage (sensor 1 and sensor 2 have < 0.5 volts and > 1.5 volts respectively when hatch is opened and vice versa when it is closed)
- The system can be programmed to pause for the required amount of time before starting the next cycle.

The LABVIEW ICI program front panel displays all sensor voltages, box, blackbody, and camera temperature, the average radiance of the image acquired, and errors, if any. Using this front panel the power can be turned off or on, the blackbody temperature can be changed, and error messages can be viewed, remotely. If the system shuts off at any point in the process, the program is reset automatically and can be started from the beginning. The MATLAB routine incorporated into LABVIEW removes dead pixels, replaces them with the nearest-neighbor average, and displays the color-coded images on the screen.

<u>Calibration</u>

The ICI was calibrated in the lab before the initial deployment, to determine the gain and offset, in a linear fit between integrated radiance and detector voltage. For each pixel, the output voltage was measured with the camera looking directly at a blackbody source at various temperatures. A linear fit to form the following calibration equation between integrated radiance and observed voltage was obtained.

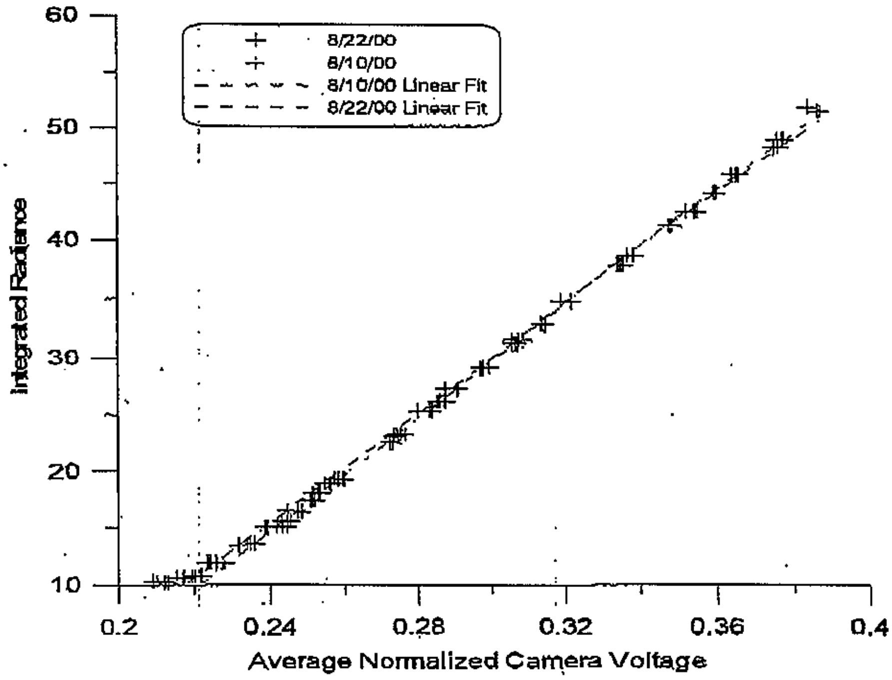
$$L = G \times V + C \tag{3.7}$$

L represents the band-integrated radiance, V is the recorded output voltage, G is the gain (change in radiance for change in voltage), and C is the offset or the voltage output due to thermal radiation within the instrument.

The camera has the ability to perform an internal uniformity correction to reduce the pixel-to-pixel variation in any image. But this offset was found to vary or drift from the normalized voltage after a few hours of operation. To overcome this inconsistency in the offset voltages an offset parameter, defined as the difference between the normalized voltage from the camera's offset correction and a fixed normalized voltage, was developed for each pixel. The fixed normalized voltage was determined by averaging and calculating the deviation from the mean voltage produced when the camera is looking at a blackbody set at 22.6 ^{0}C. Each time the camera views a blackbody or the sky, a new offset parameter is calculated using the latest offset calibration value and the predetermined fixed normalized voltage, and this offset parameter is removed from the image to get the correct value of radiance. Thus the offset value in the calibration equation changes with each acquired image but the gain was determined to be a constant.

To determine the camera gain, images of a blackbody source were taken over a wide temperature zone. The blackbody source was a blackened copper cone immersed in isopropyl alcohol and its temperature varied by adding dry ice in small increments. By calculating the integrated radiance using the Planck function and plotting it as a function of detector voltage (after subtracting the offset parameter), the gain was determined as the slope of the best-fit line for the data shown in figure 3.4.

Figure 3.4: Calibration data with ICI viewing a blackbody cone immersed in alcohol cooled with dry ice (*by Dr. Joseph Shaw and Eric Meheil*)



<u>Recalibration</u>

The data from both the Barrow and Oklahoma experiment had to be recalibrated, since the integrated radiance obtained showed deviation from that of AERI (Atmospheric Emitted Radiance Interferometer). This interferometer (Feltz et al., 2003) is a zenith-viewing instrument, and has been shown to have an absolute calibration uncertainty of less than 1% of ambient radiance (Han et al., 1997; Shaw et al., 1997). Only those time spans when there were long periods of uniformly clear or uniformly cloudy sky

ASSIGNMENT

INVENTION
AN ALARM SYSTEM FOR REMOTE SENSING EQUIPMENT Title of the Invention

I/we the undersigned inventors, are the inventors for the above identified Invention.

In consideration of the payment to me/us of the sum of one dollar ($1.00) (receipt of which is hereby acknowledged) and for other good and valuable consideration I/we hereby:

(1) Assign to COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION a body corporate constituted by the Science and Industry Research Act 1949 of the Commonwealth of Australia, with its Head Office at Limestone Avenue, Campbell, Australian Capital Territory, 2612, Australia (the "Assignee"):

(i) all my/our right, titled and interest in and to the Invention, the Application and any Letters Patent granted in respect of the Application, and

(ii) the right to file and prosecute in any country in the world any applications for registration of intellectual property right claiming priority from the Application, including applications for patents, divisionals, Continuations, Continuations-in-part, petty patents, utility models and inventors' certificates.

(2) Agree that I/we will:

(i) communicate to the Assignee, its successors and assigns, any facts known to me/us respecting the Invention, and

(ii) execute all documents, and generally do everything the Assignee, its successors and assigns may reasonably require to obtain and enforce registration of intellectual property rights or any other form of legal protection for the Invention in any country of the world.

(3) Authorise and request the Commissioner or Comptroller of Patents and such other persons as are duly appointed to administer patent and like laws in any country to issue any and all such Letters Patent and other registrable rights to the Assignee, its successors or assigns.

EXECUTED AS A DEED

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(4) Inventor's Full Name Address	Signature Dated	Witness Full Name Witness Signature
(5) Inventor's Full Name Address	Signature Dated	Witness Full Name Witness Signature

ASSIGNMENT

INVENTION
AN INFRARED DETECTION APPARATUS Title of the Invention

I/we the undersigned inventors, are the inventors for the above identified Invention.

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PCT

POWER OF ATTORNEY

(for an international application filed under the Patent Cooperation Treaty)

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Alfredo Jose PRATA

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to represent the undersigned before all the competent International Authorities

in connection with the international application identified below:

Title of the invention: APPARATUS FOR REMOTE MONITORING OF A FIELD OF VIEW

Applicant's or agent's file reference: NGM:MJL:FP20288

International application number (if already available):

filed with the following Office Australian Patent Office as receiving Office and to make or receive payments on behalf of the undersigned.

Signature of the applicant(s) *(where there are several applicants, each of them must sign; next to each signature, indicate the name of the person signing and the capacity in which the person signs, if such capacity is not obvious from reading the request or this power)*:

Signature [signature] Name John WALKER

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Date

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Position Research Scientist Date 15-10-2004

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Position Senior Principal Research Scientist Date 15-10-2004

Form PCT/Model of power of attorney (for a given international application) (July 1992)

PCT

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to represent the undersigned before all the competent International Authorities

in connection with the international application identified below:

Title of the invention: AN INFRARED DETECTION APPARATUS

Applicant's or agent's file reference: NGM:MJL:FP20351

International application number (if already available):

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