SOLMIRUS CORPORATION

Extraordinary Solutions

ASIVA

All Sky Infrared Visible Analyzer

This ASIVA capabilities report has been prepared by:

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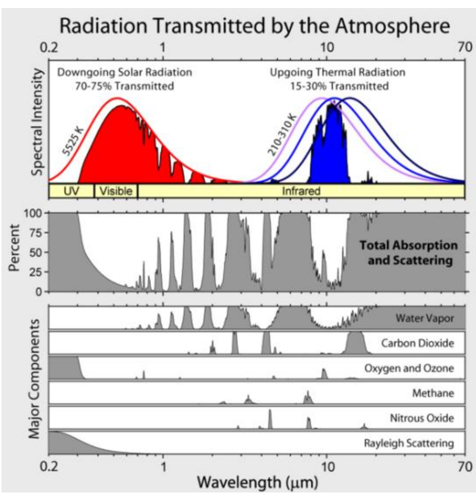
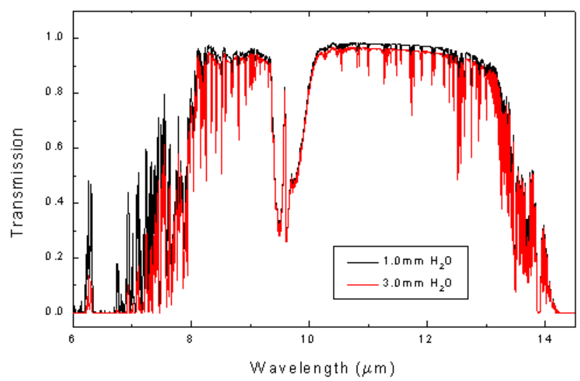
Introduction:

The Solmirus All Sky Infrared Visible Analyzer (ASIVA) is a multi-purpose visible and infrared sky imaging and analysis instrument designed to operate autonomously or as a component in an instrument cluster. Its utility ranges from astronomy and meteorology to military applications. Potential data products include the following:

- Cloud/No Cloud Reporting
- Cloud Cover Determination
- Photometric Quality Assessment
- Sky Opacity/Transmission Determination
- Visible/IR Correlation and Integration
- Water Vapor and Ozone determination
- Sky/Cloud Temperature (brightness and color) Measurements
- All-Sky (180 degree field-of-view) Radiometric Maps and Analysis

The ASIVA's primary function is to provide radiometrically-calibrated imagery in the mid-infrared (IR) atmospheric window which stretches from 8-13 microns. The following figures show clear sky atmospheric transmission in this spectral interval.

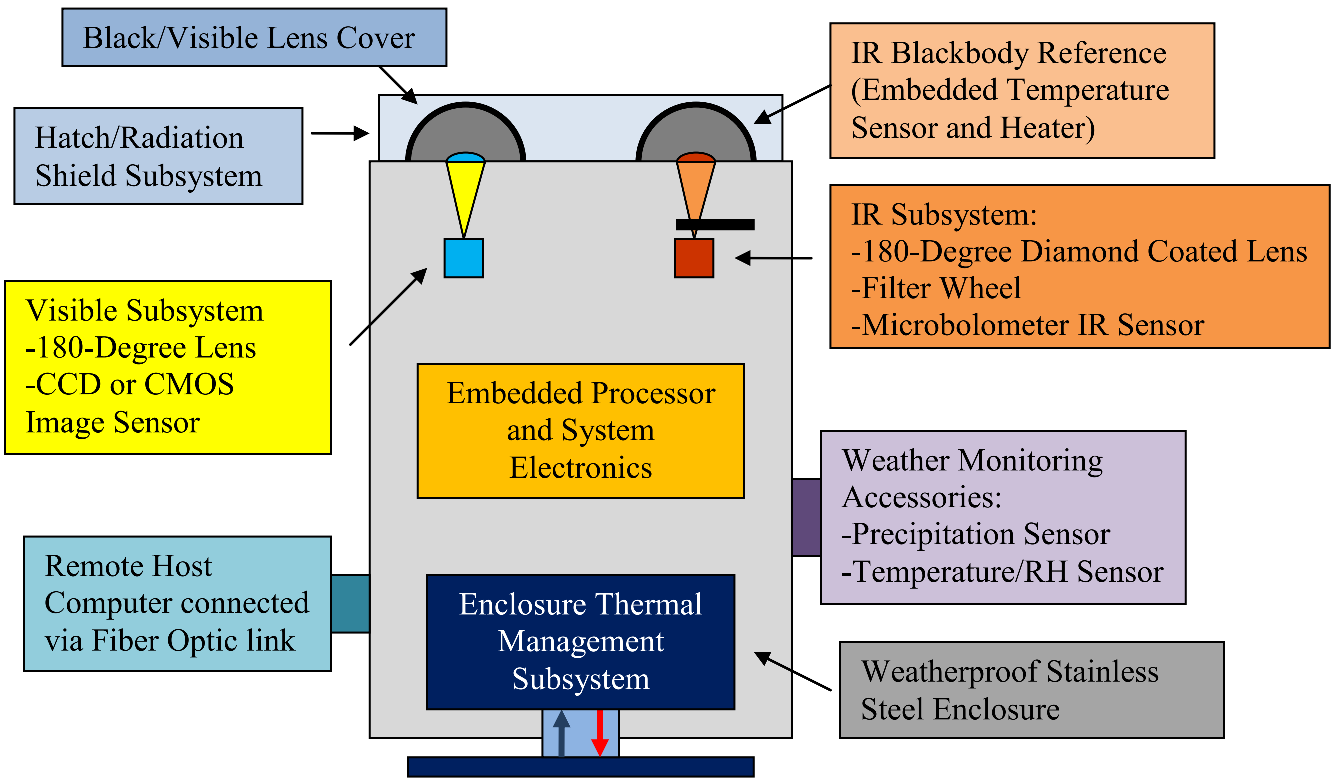




Absorption is dominated by water vapor at wavelengths less than 8 microns, by carbon dioxide at wavelengths greater than 13 microns, and by ozone near 9.5 microns. Water vapor absorption lines are seen strewn throughout this spectral interval but are least prevalent in the 10.2-12.2 micron region. Solmirus now offers a custom 10.2-12.2 micron filter for optimizing cloud/clear-sky contrast. This filter is highly recommended in detecting clouds in humid environments as well as differentiating thin clouds from variable water vapor conditions. In general, clouds are essentially gray bodies and are easily detected against the background of the highly transmitting infrared sky.

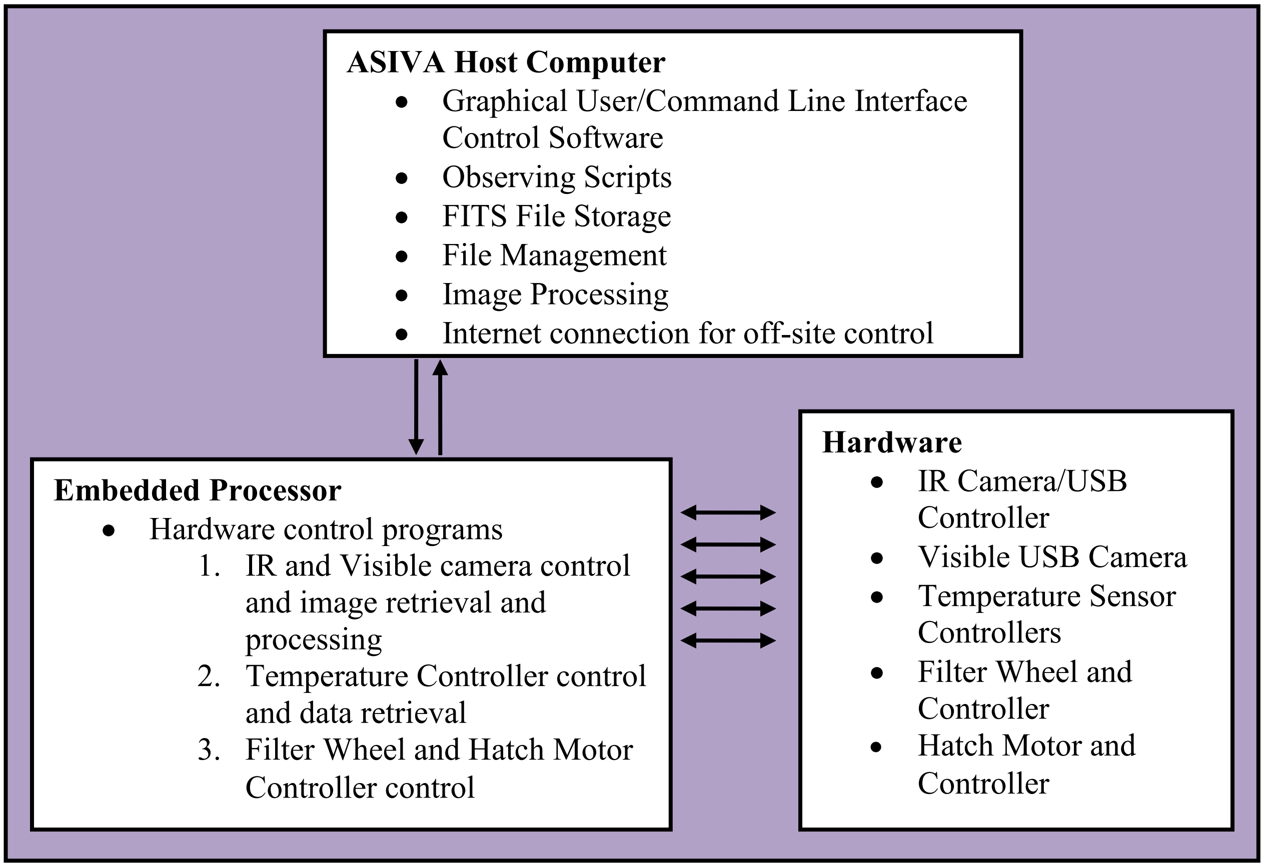
ASIVA System Architecture:

A block diagram of the ASIVA instrument and its primary functionality is shown below:



At the heart of the ASIVA instrument lays the infrared and visible imaging subsystems. The infrared subsystem includes a 640×512 uncooled microbolometer array sensitive to 8-14 micron radiation, a 180-degree (all sky) custom designed diamond coated lens, and a six-position filter wheel for use with 1-inch filters. Custom infrared filters can be cost prohibitive. We find that a good selection of affordable 1-inch filters can be found from optics manufacturer JDSU (www.jdsu.com) in their sample filter catalog. As mentioned above, Solmirus offers a custom 10.2-12.2 micron bandpass filter for optimum cloud/clear-sky contrast. The visible subsystem consists of a 1-megapixel monochrome CCD or CMOS detector coupled with a 180-degree off-the-shelf lens. Color CCD or CMOS detectors are also available upon request.

The brain of the ASIVA instrument is the embedded processor that communicates with and controls the imaging subsystems and other subsystems such as the hatch-motor, filter-wheel, temperature-meters, and weather-monitoring subsystems. Data (both raw and processed) is passed over a fiber optic link to the host computer where it can be archived and displayed. Operational control of the ASIVA instrument, additional image processing, and off-site control through the Internet is done via the host computer. Operational control software with either graphical user or command line interface has been developed and is customizable to the customer's needs. This operation and control architecture is illustrated in the following block diagram.



The first ASIVA production model was built for the Large Survey Synoptic (LSST) project and is currently being operated on Cerro Pachon, Chili. In preparation for an IRSI (Infrared Sky Imaging) inter-comparison study held in Oklahoma in August/September 2007, Solmirus prepared a demonstrational unit (D-ASIVA) that incorporates new innovations based on lessons learned from the LSST-ASIVA design.

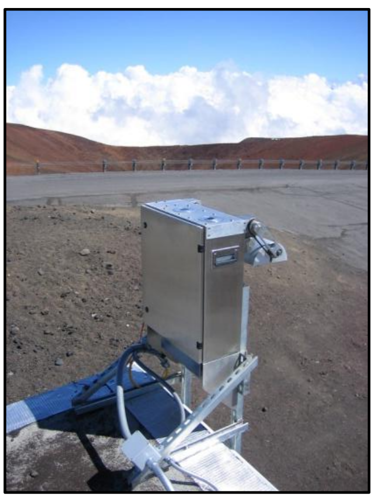
LSST-ASIVA in Colorado Springs, CO

D-ASIVA in Oklahoma

In particular, a new hatch mechanism was designed and built to provide the following improvements over the previous model:

- The blackbody reference remains in the same protected orientation (pointed downward) as the hatch mechanism is opened and closed.
- The hatch drive motor, position encoder, and limit switches are housed within the enclosure for better protection and durability.
- Temperature sensors are embedded in the IR blackbody reference for accurate in situ temperature measurements.
- As part of the hatch, a black painted reference is now used to cover the visible camera lens for protection and dark subtraction purposes. The LSST-ASIVA used a Lexan dome and internal shutter.

The D-ASIVA is outfitted with an autonomous enclosure thermal management system designed to handle high internal temperatures possible when operating in the Oklahoma summer environment. This feature is now available on all ASIVA systems. In preparation for a June-August 2008 demonstration on Mauna Kea, HI the D-ASIVA was fitted with an insulated radiation shield. This shield surrounds the IR blackbody reference allowing it to better track the ambient temperature as well as improves its performance in inclement weather. A heater element is embedded within the infrared blackbody reference for accurate in situ temperature/flux calibration. These principle modifications are shown in the images below. Slight modifications to this hatch design are now being integrated in an ASIVA system now being prepared for permanent installation at the Mauna Kea Observatories, HI.

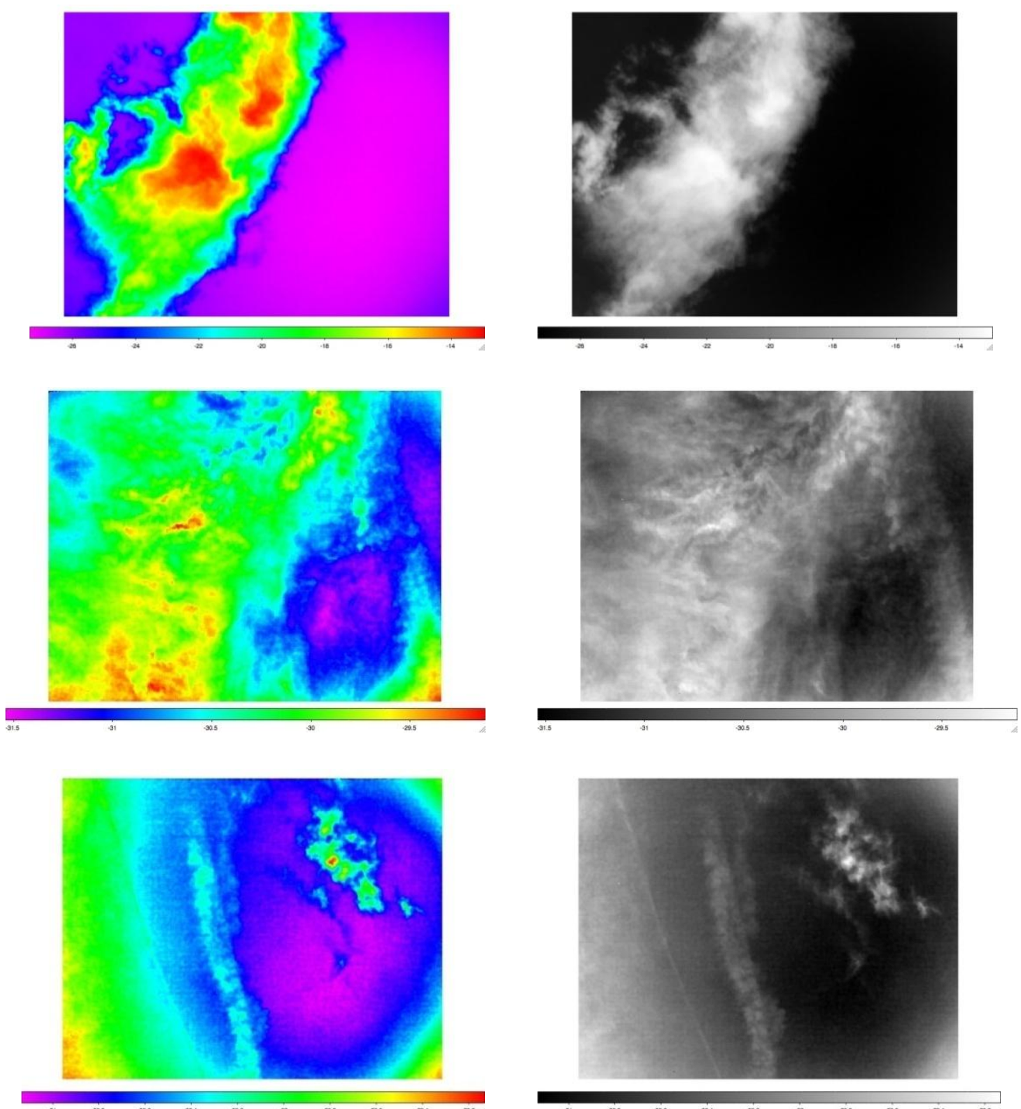


D-ASIVA on Mauna Kea, HI

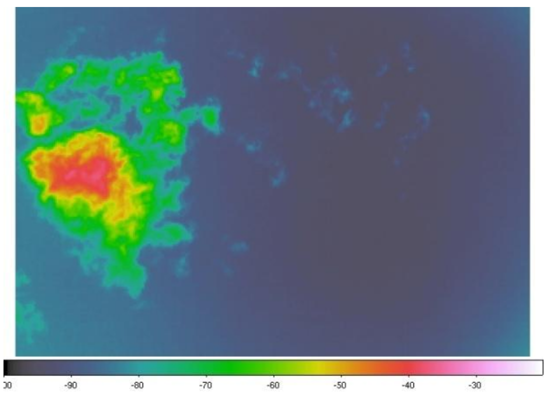
D-ASIVA in Colorado Springs, CO

ASIVA Performance and Data Products:

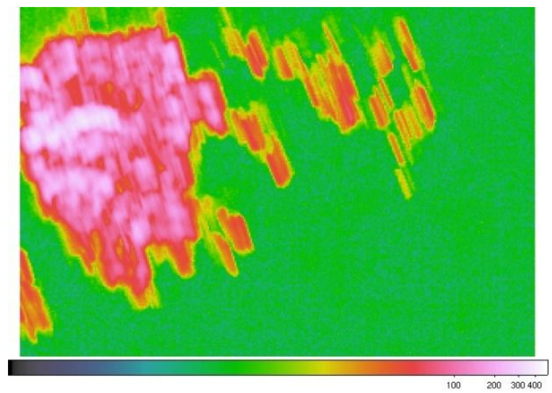
The ASIVA showcases a microbolometer infrared sensor that demonstrated an order of magnitude improvement in signal-to-noise performance over previous generations of the ASIVA instrument. Earlier models including the LSST-ASIVA, utilized a BST (Barium-Strontium-Titanate) based infrared detector. The microbolometer provides data that allows for absolute calibration, something that has proven to be extremely difficult for the BST detector. The microbolometer provides much better sensitivity to thin clouds as well as the means for accurate determination of both brightness and color temperature of the sky and clouds. The D-ASIVA utilizes a smaller 324x256 format array though as mentioned above, current ASIVA systems now offer a larger 640x512 format array. Both sensor arrays offer identical signal-to-noise performance. The following images represent a sample of radiometrically-calibrated images taken with the D-ASIVA instrument (38degx50deg FOV) in Colorado Springs, CO. Flux values are listed in $W/m^2/sr$ and are measured relative to the ambient temperature blackbody reference. For reference $BB_{8-13\mu m}(300)$ = ~50 $W/m^2/sr$ and $BB_{8-13\mu m}(273)$ =~30 $W/m^2/sr$.



A variety of mid-IR data products are available for the ASIVA. Our current data retrieval scheme goes as follows: Sky images are stored as 3-dimensional FITS images 640x512 pixels (324x256 for the D-ASIVA system) by 16 images deep. Each image in the 3-D FITS image represents ~0.5 seconds exposure acquired by co-adding sixteen (16) 1/30th second frames. The 3-D FITS image can therefore be co-added to provide a single ~8 second exposure. An advantage to this data acquisition scheme is that it allows for the computation of the standard deviation of each pixel across time and is shown to be an excellent discriminator of cloud structure. The following images were acquired by D-ASIVA in Colorado Springs, CO in May of 2008 shortly before deployment to HI.



Brightness Temperature Image (single ½-second exposure frame)



Standard Deviation Image (16 ½-second exposure frames used)

The D-ASIVA currently achieves a Noise Equivalent Power (NEP) of 0.016 W/m^2/sr for a single 0.5 second image. NEP is determined by differencing consecutive images and calculating its RMS fluctuations. Similar results are obtained by calculating the RMS fluctuations for each pixel using the 16 individual values stored for that pixel in the 3-D image file. The NEP specification equates to a Noise Equivalent Temperature Difference (NETD, computed at 300 K) of 20 mK which compares very nicely with the camera manufacturer's quoted NETD specification for a single 1/30th second frame of 85 mK. At T = 273 K, one can also translate the NEP specification to a noise equivalent optical depth of 0.0005. This means that one should be able to detect optical depth (and therefore sky emissivity/transmission) variations at the 0.5% level with a signal to noise ratio of 10. A factor of four improvement in S/N ratio is obtained by co-adding the 16 images stored in the 3-D FITS file. We anticipate a reduction in S/N ratio of ~5 when utilizing narrower (~1-micron) bandpass filters.

This document represents the status of the ASIVA instrument as of March 5, 2009. Please contact Solmirus (www.solmirus.com) for further details.