The Australian Resource Information and Environment Satellite (ARIES), Phase A Study

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Abstract. A Phase A study for the ARIES space-based hyperspectral remote measurement program has been undertaken by the ARIES consortium of AUSPACE Limited, The Australian Centre for Remote Sensing (ACRES) and the Commonwealth Scientific and Industrial Research Organisation Division of Exploration and Mining (CSIRO DEM). AUSPACE has undertaken the space segment study, ACRES the ground segment design, and the CSIRO has undertaken overall project management for the study, market analysis and algorithm development. The paper describes the outcome of the study including space segment design and algorithm development, and the planned mission. A description of another Australian satellite program, FEDSAT-1, and its links to the ARIES program, is included.

Introduction

The Australian Resource Information and Environment Satellite (ARIES) will be a lightsat with an advanced hyperspectral remote sensing instrument package. ARIES will allow the remote exploration for minerals from space on a world-wide basis. This functionality will also allow it to perform a range of other tasks, such as regional geological mapping, environmental and agricultural monitoring and mapping. By incorporating on-board storage, users will be able to access imagery 'over the horizon', to satisfy the needs of mining companies, who explore on a world-wide basis.

Hyperspectral remote sensing satellites differ from conventional panchromatic or multi-spectral systems such as SPOT or Landsat by subdividing the infrared and visible reflected flux from the Earth into many narrow, accurately characterised spectral channels[1]. This approach, when coupled with sophisticated algorithms such as those developed by researchers at the CSIRO Division of Exploration and Mining (DEM), allows 'remote measurement', rather than simply 'remote sensing' of variables such as mineral type and abundance, on a global basis.

A six month Phase A design study of the ARIES space segment was undertaken by AUSPACE, in parallel with examination of the ground segment by the Australian Centre for Remote Sensing (ACRES) and the algorithms for mineral mapping by the CSIRO Division of Exploration and Mining (DEM). The space segment study focussed on the definition of system requirements, mission analysis and instrument design, which is the critical determinant of mission performance. The team has used typical lightsat platform performances in the study, and use of a commercially available platform was assumed.

The ARIES system is required to provide the performances shown in Table 1.

Space Segment Design

The ARIES spacecraft will consist of an advanced, 3-axis stabilised lightsat bus, with an instrument package consisting of a common telescope, two spectrographs, a panchromatic (PAN) imager, and the associated focal planes and data handling electronics.

The combination of a large diameter telescope with sensitive detectors will allow ARIES to provide data in the visible and short wave infrared wavelength range from 400 nm to 2500 nm with high spectral resolution at high signal to noise.

The instrument package will include a high-speed X-band downlink, and large solid state memory, to allow over-the-horizon imaging for global mineral exploration.

Mission

The ARIES spacecraft is required to acquire high-quality spectral and spatial data, with a revisit time of 7 days or less. In order to achieve good signal to noise, the spacecraft will be in a 500 km, polar, sun-synchronous orbit.

To achieve a good revisit time with a limited swath (15 km), the spacecraft will use off-axis pointing. This will be limited to ±30 degrees, in order to minimise spatial distortion, and loss of signal to noise at large off-axis angles.

The pointing will be achieved by off-nadir pointing of the satellite along the roll axis, which limits the rate at which the movement can be achieved, but is more reliable and cheaper than the use of a pointing mirror.

The satellite will have a local crossing time of about 12 noon, in order to minimise the impact of shadows, and maximise the solar flux, and thus the signal to noise delivered by the instrument. Analysis of cloud data for a 3 year period indicates that a noon orbit is better than a 9am orbit (for example) for most regions of interest.

Table 1: ARIES-1 Specifications.

Requirement	Specification
Spectral Coverage and Band Spacing	• Contiguous Coverage from 400 - 1000 nm with a minimum of 20 nm band spacing; • Contiguous coverage from 2000 - 2500 nm with a minimum of 16 nm band spacing. • Two sets of three bands centred on 940 nm and 1140 nm with minimum band spacing of 16 nm for atmospheric correction. • Contiguous coverage from 1000 - 2000 nm spectrally binned up and optionally available.
Signal to Noise Ratio	• Minimum of 600:1 in the VISNIR at 600 nm; • Minimum of 400:1 in the SWIR at 2100 nm.
Spatial Resolution	• 30m at Nadir, spectral sensors; • 10m at Nadir, PAN sensor;
Calibration	On-board radiometric calibration to 6% accuracy
Ground Swath	15 km at nadir
Revisit Time	Less than 7 days with +/- 30 degree off-nadir pointing
Pointing Accuracy without Ground Control Points	+/- 15m at nadir
Equatorial Crossing Time	12 noon, +/- 1 hour
Data Acquisition Lead Time Order Delivery Time	7 days 2-7 days
Data Delivery	On-line, CD-ROM, Magnetic Tape
Mission Life	3 Years minimum, 5 years planned

ARIES will have a solid state recorder with about 44Gbits of memory, to allow ten minutes of hyperspectral data to be acquired over the horizon, and stored for subsequent downlink over Australia (Alice Springs, Hobart), or overseas ground stations. This will allow mineral exploration companies to achieve around-the-world remote sensing from their home base.

Spacecraft

ARIES will be a single-instrument spacecraft, on a lightsat platform, so that the design of the instrument can take advantage of the simplicity of a single-instrument mission. This allows trades in favour of combined functionality (e.g. thermal and mechanical control in the instrument computer), rather than through separate units, in order to minimise the mass, power and volume of the instrument, and hence the cost of the mission.

The ARIES design will also seek to minimise the interface complexity between the platform and the instrument, to allow parallel development of the two sub-systems, with a limited integration task once they are brought together at the platform vendor's facility. The

ARIES design also aims to minimise the performance demands on the platform, consistent with what is available at low risk, and consistent with the performance requirements of the mission.

Platform

The ARIES Phase A Space Segment Study defined the requirements for the lightsat platform. The design goal was to utilise an available platform, and not to require expensive development or customisation of the platform, in order to meet the cost constraints of ARIES, as a commercial programme. The design took into account the published capabilities of lightsat platforms, to ensure that the space segment design will be realisable within the schedule, cost and risk constraints of the programme.

ARIES will use a 3-axis stabilised platform, with sun-tracking (or fixed) gallium arsenide solar arrays, a nickel hydrogen or nickel cadmium battery, star trackers, a set of momentum wheels and magnetotorquers, a set of thrusters for orbit maintenance and wheel desaturation, a reconfigurable on-board platform control computer, and an S-band Telemetry, Tracking and Command (TT&C) subsystem.

The design of the platform-instrument interfaces will allow for ease of integration and test at platform, instrument and spacecraft levels. A schematic of the platform-instrument interface is shown in Figure 1. The instrument will probably have its own computer, to allow separate testing of the two subsystems prior to integration, and to minimise the cost and risk of software integration late in the programme. The two computers will communicate via a MIL-STD-1553 serial bus. The other key interfaces will be dual redundant power buses from the platform power subsystem, survival heater and temperature sensor lines, and pyrotechnic lines. The instrument will provide its own data downlink capability.

Three candidate platforms were shortlisted by competitive tender process during the Phase A study, and a final selection will probably be made early in the Phase B program. A representation of the satellite on-orbit is shown in Figure 2. (This diagram shows one of the three candidate platforms, and is not meant to be an endorsement of that specific platform).

The ARIES instrument will consist of an off-axis telescope, feeding two spectrographs via a common slit. A PAN imager will provide a higher resolution wide band PAN image for feature sharpening. The analogue image data from the three focal planes will be quantised, formatted in high speed electronics, and stored in a solid state recorder. When ARIES is over a suitable ground station, the data will be down-linked at X-band at 150 Mbits/second in a format compatible with Landsat-7 receiving stations.

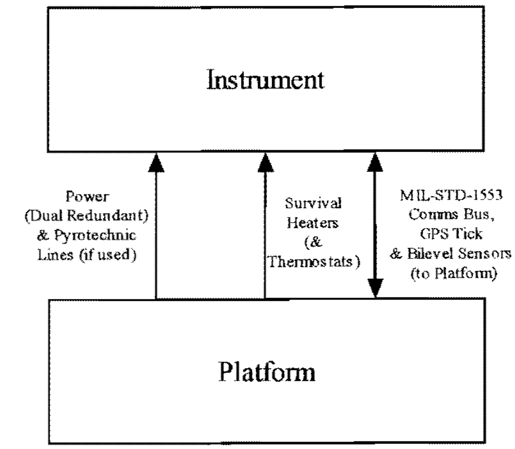

Figure 1. Instrument and Platform Interfaces

Instrument

The general layout of the ARIES instrument is shown in Figure 3. This consists of a common telescope, feeding two spectrographs via a single slit (for band-to-band registration), with the associated electronic modules mounted around the central optical bench, on radiator structures.

Optical Subsystem

The instrument will use a three mirror anastigmatic (TMA) telescope configuration. The TMA design gives good image quality in a compact design with low susceptibility to scattered light. The telescope will be well baffled, to reduce scattered light, and heat loss from the optics.

During launch, the telescope will be protected by a cover which will be deployed after initial orbital refinement. The cover will be re-closeable, and may form part of the calibration subsystem.

A transmissive slit will feed the two spectrographs, with a collimated beam via a dichroic beamsplitter. One spectrograph will operate over the range 400 - <1000 nm in the visible and near infrared (VISNIR), and the other will run from >1000 - 2500 nm in the short wave infrared (SWIR).

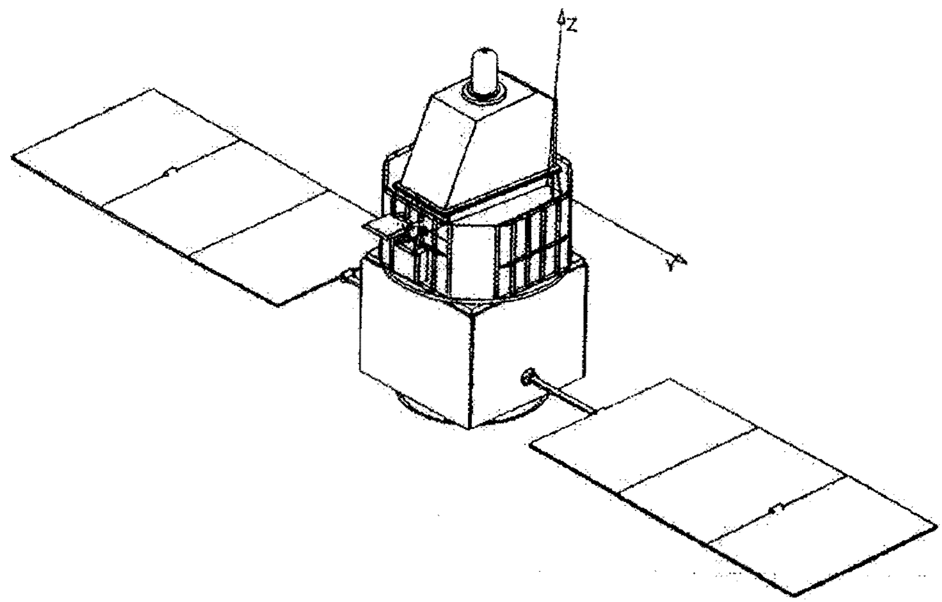

Figure 2. ARIES Spacecraft in On-Orbit Configuration

The VISNIR data is of interest for the discrimination of vegetation in the mineral scene, and in its own right for agricultural and environmental users.

In addition, the water vapour content of the atmosphere, which is vital for correction of the data to absolute reflectance, can be determined from the absorption feature at about 940 nm.

The SWIR data set in the region from 2000 - 2500 nm is of prime importance to the mineral community. In addition, 3 channels will be sampled around 1140 nm, a second water vapour absorption feature. The SWIR data will be obtained with a single spectrograph covering the 1000 - 2500 nm range and a single focal plane.

The PAN imager will consist of a linear visible CCD with a broad band dichroic filter to define the bandpass. The PAN imager will share flux with the VISNIR spectrograph. This approach overcomes the need for a tight short-term micro-vibration requirement on the spacecraft, to ensure that the PAN and spectral images are co-registered.

An on-orbit calibration capability will be provided, to allow radiometric and spectral calibration to be done. This will use internal light-emitting diode (LED) and incandescent lamp sources, and sunlight, for spectral and radiometric calibration. This facility will be augmented by use of ground reference targets, and a comprehensive pre-launch calibration process.

Focal Planes and Cooling

The instrument will have three focal planes;

- A 2-D silicon CCD for the VISNIR spectrograph;
- A 2-D CMT-on-Si focal plane, for the SWIR spectrograph.
- A 1-D silicon CCD for the PAN imager.

The 2-D Si CCD will be a semi-custom array, and will be rear-illuminated for increased sensitivity. The CCD will be cooled via a radiator to about 270K, and stabilised, to minimise the impact of thermal noise. It will have 2 readout ports, to minimise the per-chain readout rate, and hence noise.

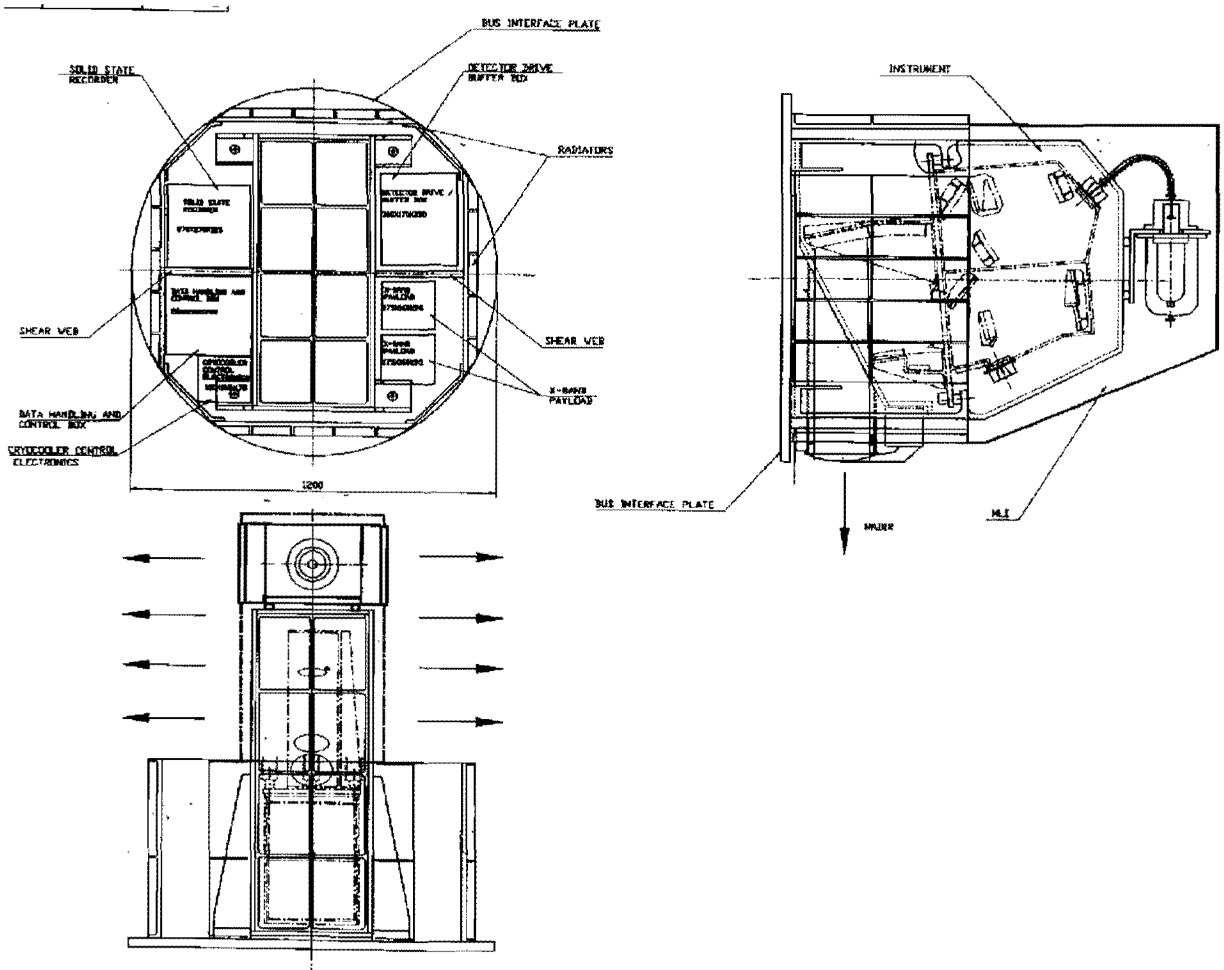

Figure 3. General Layout of ARIES Instrument

The 1-D Si sensor, likewise, is not seen as a complex system. It will be stabilised to 293K via a radiative cooler and resistive heater. It will have a single analogue chain, although it may have two readout ports, for redundancy. The pixel dimension will be about 1/3 that of the SWIR spectrograph detector, to match the resolution requirement of the PAN imager compared to the spectrograph sensors.

The 2-D CMT sensor will be a developmental item, benefiting from the work done in Europe and the US for satellite SWIR sensors. It will consist of a 2-D array of CMT diodes bump-bonded to a 2-D silicon readout array of transimpedence amplifiers. The CMT array will have to operate at about 120 K, in order to minimise thermal noise. The cooling will be provided by a mechanical cryo-cooler. The coolers will dump their heat to small radiators on the East and West sides of the instrument.

Both 2-D arrays will operate in snap-shot mode, to minimise the along track motion-induced smear, which would translate into band-to-band mis-registration.

Detailed performance modelling of the optics, spectrographs and detectors, using Lowtran to determine input flux levels, has been undertaken to confirm the ability of the satellite to meet the design requirements of high signal to noise, coupled with high spectral resolution.

The video data chain for each array will be similar. Each focal plane will have clocking electronics, synchronised to a common frame start pulse and pixel pulse from the data handling electronics. The off-chip video signal will be buffered, filtered and level shifted, prior to quantisation in the sensor subsystem electronics.

The complete data set from the focal planes will be buffered into a FIFO and transmitted to the data handling electronics.

Electronic Subsystem

The electronic subsystem will consist of the sensors and their associated analogue electronics, the data handling electronics, the data downlink electronics, and the instrument control electronics. The layout of the electronics subsystem is shown in Figure 4.

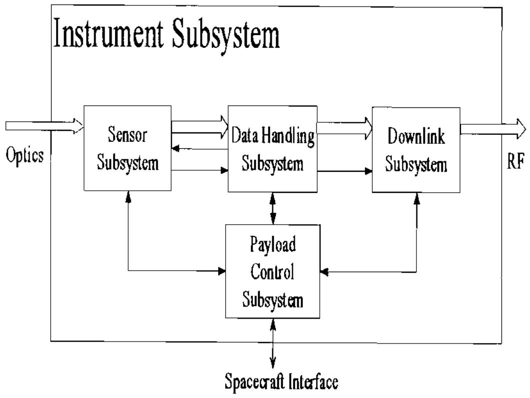

Figure 4. Layout of ARIES Instrument Electronics

Data Handling Electronics

The data handling electronics sits between the sensors subsystem (input) and the X-band downlink electronics (output). It provides the data interface and buffering from the sensor subsystem, undertakes lossless compression of the sensor data, formats the data into CCSDS-compatible packets, and stores the data in a solid state recorder. It also provides the control and data interface to the platform processor, for overall instrument control, timing and synchronisation function.

At the interface from the sensor subsystem, the data will be buffered, and the baseline set of spectral bands will be selected, and framed with timing and AOCS data. The selection of bands will be programmable under ground segment control, to allow different data sets for different customer requirements, to maximise the utilisation of the solid state recorder capacity. The data stream will then be compressed in real time with lossless compression. at a (conservative) compression ratio of 2:1.

The image data will be framed into data sets, with a header line defining the frame number, line number, UTC time, current GPS pseudo-ranges, local clock-to-UTC offset error, and AOCS offsets and rates. This approach will allow a ground station to recover and reconstitute the data set without access to the S-band TT&C data.

The data rate from the focal plane will be of the order of 100 Mbits/s, for the baseline data set of VISNIR, SWIR and PAN channels. After compression, this will be about 50 Mbits/s. The compression will be achieved through either an off-the-shelf chip such as the USES chip from Goddard Space Flight Centre and the University of New Mexico, or a mission-specific gate array.

A high density solid state recorder will ingest the compressed data, for storage until the next pass over a ground station. Given that a high latitude ground station is likely to be used, the typical storage time for the recorder will be less than 1 orbit. The recorder will be a commercially-available, flight proven unit, and will have error-correcting memory.

The ARIES design will allow for real-time downlinking of data.

X-Band Downlink

Because of the high data rates and consequent data volumes for ARIES, a high speed X-band data link is required.

The current standard X-band links are represented by programmes such as SPOT and ERS, with 105 Mbit/s downlink channels. For ARIES, it is proposed to use the new LandSat-7 compatible 150 Mbit/s data format, in order to maximise the data downlinked per 10 minute pass (8 minutes for Alice Springs).

One or two quasi-omnidirectional antenna will be used for data down-linking. Two antennae, arranged 60 degrees apart, ensures that one of the two antennae will be pointing towards the ground for the extremes of off-axis pointing. These will be fed from two cross-strapped solid state power amplifiers (SSPAs), for redundancy, and these in turn by two modulators. Analysis of the trades between increased SSPA power, an agile antenna or multiple antennae is continuing.

Instrument Control Computer

As a baseline, the ARIES instrument will be controlled by its own computer, which will communicate with the platform control computer across a MIL-STD-1553 link. This approach is proposed to minimise the interface problems of combining instrument and bus code into the one computer, and to facilitate the assembly, integration and test task at instrument and spacecraft level.

The computer will not access the high rate data stream, but will only have to work at lower rates. Its functions will include acquisition of instrument telemetry data for transfer to the platform computer, thermal control of the instrument, control of the instrument mechanism drive electronics (for calibration mechanisms), sequencing the data downlink tasks, commanding the solid state recorder, writing the defined spectral band set to the data handling electronics on a per-observation basis, and writing AOCS information from the bus to the framing electronics on a per-second basis.

As such, a relatively low powered computer, such as a 1750, may be used. The trades between separate platform and instrument computers, and instrument control within the platform computer will be revisited in Phase B, as part of the final platform selection process.

Structural and Mechanical Subsystem

The ARIES instrument structure will consist of a stable optical bench, on which the foreoptics and spectrograph optical elements are mounted, surrounded by an instrument structure, to which it is supported at three points. The overall instrument will be supported by the main instrument structure, consisting of the platform interface plate, and an external thermal control structure.

In order to meet the sub-pixel geolocation requirements of the mission, star trackers will be mounted on, or near, the optical bench. Tight stability requirements will be imposed on the optical bench structure and the overall instrument structure.

The optical bench may be made from metal or carbon fibre, depending on the thermo-mechanical stability requirements derived from ongoing structural modelling. The surrounding instrument housing will be carbon fibre/aluminium honeycomb. This will support the cryo-cooler, calibration unit, baffling etc., and will provide a stable thermal bath for the optical bench structure.

The instrument housing will be mounted to the platform interface plate. The instrument electronics will be mounted to the platform interface plate, or to parts of the main instrument structure or radiator panels, depending on their thermal control requirements and mass distribution issues.

The design has aimed to reduce the cost and complexity of the instrument by minimising the number of mechanisms. As a baseline, a foreoptics cover will be used, to protect the instrument optics during launch. This will be a normally open, recloseable cover, to protect the optics during orbit maintenance manoeuvres, and may form part of a foreoptic-to-focal plane calibration chain. It will be magnetically latched closed during launch, with an unlatching solenoid. There will also be a shutter mechanism within the calibration chain to prevent stray light during normal operation, and protect the diffuser surface against contamination on-orbit. All electro-mechanical mechanisms will be double wound and driven from redundant electronic drivers, and rotary mechanisms will have redundant bearings or a similar means to minimise sticking.

Thermal Subsystem

The thermal subsystem for ARIES will include a mechanical cryo-cooler to provide the required 120K operating temperature for its SWIR focal plane, and a radiative cooler with trim heaters for the PAN and VISNIR detectors. It will also implement the tight (~1-2°C) optical bench thermal control function, and the wider (±10°C) instrument thermal control function.

Thermal control will be provided by radiators (which, as structural or quasi-structural elements, are part of the mechanical subsystem), with electrical heaters, sensors and thermostats. For the tight thermal control of the optical bench, control of heater powers and distribution of powers will be achieved via algorithms in the control electronics central processor, and its associated thermal control electronics unit. For the less demanding thermal control of the instrument overall, a combination of operational and survival heaters and thermostats will be used.

Launcher

The launcher for ARIES will be selected on the basis of launch capacity, fairing dimensions, reliability, price and location of its launch site. The launch mass of the spacecraft will be less than 450 kg, which can be accommodated by a range of light launch vehicles.

A prime and backup launcher will be selected, and the ARIES launcher interface will be made compatible with both, for risk minimisation.

Space Segment Implementation

The ARIES implementation programme will take 36 months, from the start of the Preliminary Design Phase until the launch of the spacecraft.

The instrument will be designed and built by AUSPACE, at its Canberra facility. The bus will be built in parallel at the platform vendor's facility. Both subsystems will be subject to characterisation and testing, prior to their integration at the platform vendor's facility, and system level functional and environmental testing.

The platform, as an off-the-shelf unit, will be implemented in a single model, the flight model. The instrument will be implemented as a series of unit-level breadboards in key technology areas, a structural-thermal model, an engineering model of the complete instrument electronics with a platform electronics simulator and the proto-flight model.

The areas to be bread-boarded will include components of the optical chain (depending on the final design of the optics and its manufacturing and alignment complexity), and the sensor sub-systems (depending on the nature of the development contracts with detector suppliers, such bread-boarding may be part of their procurement contracts, rather than at instrument level).

The instrument structural-thermal model will consist of thermally representative mass dummies of the electronics and detectors, with the flight structure and prototype optics (some of which may also be mass dummies). Following thermal, thermal vacuum and mechanical environmental testing and model validation, the STM structure will be modified or rebuilt as required, and refurbished as the flight unit.

Ground Segment

The ground segment for the ARIES programme will consist of a data reception, processing, dissemination and archiving capability, and a spacecraft tracking, telemetry and tele-command capability. The data communications interface between the ground and space segments will be an X-band downlink, defined by CCSDS specifications, and operating at 150 Mbits/second, to be compatible with the Landsat-7 format.

The TT&C sub-system will consist of the platform TT&C sub-system, and the ground sub-system. The interface between the ground and space segments of the TT&C sub-system will be via an industry-standard S-band bi-directional link.

The X-band ground segment design and subsequent implementation will be the responsibility of the Australian Centre for Remote Sensing (ACRES), who have undertaken the Phase A Ground Segment design for ARIES. Data will be received in Australia, at the Tasmanian Earth Resources Satellite Station (TERSS), and at one or two high latitude stations (such as Kiruna and Alaska). Data will be processed to Level 0, catalogued, and archived at one or more sites. Access to the data will be via the internet, to provide access to users around the globe. Users will also be able to submit requests for the acquisition of scenes through the internet, and monitor the status of the acquisition.

Development of Data Processing Algorithms

A key part of the Phase A program has been the ongoing development and refinement of algorithms for the interpretation of hyperspectral data for geological use. This work has developed from several years of investigation by the CSIRO Division of Exploration and Mining, most recently involving data from the NASA AVIRIS instrument, developed by the Jet Propulsion Laboratory.

The infrared and visible flux received at the satellite includes the imprint of the solar spectrum, atmospheric scattering and atmospheric absorption, particularly by water vapour. Fortunately, hyperspectral data contains spectral signatures due to these effects, and allows the data to be self-reducing. ARIES will obtain data from the two water vapour bands at 940 nm and 1140 nm, and these, combined with the high signal to noise data from the visible and key 2 um - 2.5 um bands, allows mineral identification to be undertaken entirely by remote sensing.

The process of mineral identification can be undertaken in different ways, and much work is underway to optimise these methods[2,3]. The approach used for the ARIES data simulation involved the following steps;

- Calibration of the raw radiance data from the instrument with pixel-by-pixel calibration models for the instrument. This produces a "radiance cube";
- Removal of atmospheric effects to obtain reflectance data and a water vapour image.

(These two steps are called Level 1 processing);

- Performing a minimum noise fraction transform to model and whiten the noise in the image, and to decorrelate the data and determine its dimensionality;
- Performing a pixel purity index (PPI) calculation to approximate a convex hull calculation of the pixels with the most pure spectra (ie pixels consisting of a single mineral) in the image[4];
- Grouping and clustering the pure (end-member) pixels, to complete discovery of end-member pixel classes;
- Determining the mineral or minerals associated with the end-member pixel clusters, through the use of a library of reference mineral spectra;
- Unmixing the remaining pixels in the scene through a linear spectral mixing model (ie pixels that are not pure are assumed to be linear mixtures of minerals from the purest pixels);
- Performing quality-assurance checks on the resultant mineral map. This set of steps is called the level 2 processing;
- Using ground truth data and the ARIES spectral library to produce a spatial mineral map. Different types of maps will be delivered, with external data from other sources (such as digital terrain models). This will include overlaying the PAN image (with 10m resolution) on the mineral map (with 30m resolution), to provide image sharpening, and a more intuitive user interface. (Operational data processing will not require the use of ground truth data, following commissioning of the satellite).

In order to be able to obtain absolute reflectance data and thus undertake the complex chain of processing, the instrument must be stable and well characterised, through a combination of pre-launch and on-orbit calibration processes. It must also deliver an adequate combination of spectral resolution and signal to noise in each spectral band, most critically in the geologically-important 2.0 - 2.5 micron band.

A key part of the ARIES Phase A program was to demonstrate this processing sequence, using data sets obtained by the AVIRIS sensor[3]. The AVIRIS data was resampled to provide ARIES-like spatial and spectral resolution. Workshops were held with project sponsors, to train geologists in the processing methodology, and demonstrate the power of the technique.

While the processing steps identified above are numerically intensive, they are already within the capabilities of desktop personal computers. Refinements of the processing algorithms, coupled with ongoing improvements in computer capability, will allow real-time data reduction to be undertaken in a commercial data delivery environment.

The FedSat-1 Program

The CSIRO and AUSPACE are also involved in developing a microsatellite in a similar timeframe as the ARIES program. Known as FedSat-1, the mission will be managed by the newly-formed Cooperative Research Centre for Satellite Systems, whose headquarters are co-located with the CSIRO Office of Space Science and Applications (COSSA) in Canberra. The Australian Government's Cooperative Research Centre program is designed to encourage industry, research organisations and universities to collaborate on technologies of national significance. The core partners of the Centre for Satellite Systems are CSIRO; AUSPACE Limited; Vipac Engineers and Scientists Ltd; the ARIES Consortium; the University of South Australia; Queensland University of Technology; and the University of Newcastle.

FedSat-1 will be a 50 kg class satellite, with four experimental payloads;

- An advanced magnetometer, for studying solar-terrestrial physics and the geomagnetic field;
- An advanced communications payload with Ka band, L band and VHF experiments in inter-satellite, satellite to ground and multi-satellite communication;
- GPS-based navigation and high-performance computing package, for ionospheric and atmospheric sounding and satellite navigation;
- A spacecraft engineering test package including solar power generation.

The project management and systems engineering for the program will be undertaken at COSSA's headquarters in Canberra, with inputs from AUSPACE Limited, who with Vipac Engineers and Scientists Limited will also lead the assembly, integration and test phase of the program.

FedSat-1 will be launched as a secondary passenger into a low earth orbit in 2001, the centenary of Australian Federation, and will serve as a stimulus to space engineering within Australian universities and industry.

The Cooperative Research Centre for Satellite Systems will also participate in the application development program for ARIES.

Conclusion

The Phase A study of the ARIES-1 program has demonstrated that a high performance lightsat can be built, which will deliver key mineral exploration and environmental data to the world community, when coupled with state-of-the-art algorithms for mineral mapping. This conclusion was endorsed by the system design review undertaken by a panel of Australian and international space and instrumentation experts.

More information about ARIES, and about FedSat-1 is available at <http://www.cossa.csiro.au/>.

Acknowledgments

AUSPACE wishes the acknowledge the role of the Commonwealth Department of Industry, Technology and Tourism in partial funding of the study; and the Australian Mineral Industry Research Association (AMIRA) and the UK Mineral Industry Research Organisation (MIRO) for coordinating the sponsorship of the study by member companies. The sponsoring groups for the Phase A study were Anglo American Corporation of South Africa, the Australian Geological Surveys Consortium, the Canadian Centre for Remote Sensing, the European Geological Surveys Consortium, the Natural Environment Research Council (UK), Phelps Dodge, Outokumpu Metals and Resources Oy, Rio Tinto Zinc, Sumitomo Metal Mining Oceania Pty Ltd, and Western Mining Corporation Resources Limited. The authors wish to acknowledge the work by the space segment team of Gerald Bolding, Dave Bundy, Stan Dougan, Roger Franzen, Lindsay Harkness, Mike Petkovic, Leigh Pfitzner and Danny Ruttan. Analysis of data archiving and dissemination was undertaken by the CSIRO Mathematical and Information Sciences. The role of the JPL AVIRIS team in the development of AVIRIS and its data processing algorithms, along with Dr Joe Boardman from the University of Colorado, is warmly acknowledged. Optical design for the study was undertaken by Damien Jones (Prime Optics). Systems and optics support was provided by Matra Marconi Space, and in particular Dr Richard Scaddan and Ben Olivier from MMS Bristol.

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