The space system for the High Energy Transient Experiment .

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Introduction

The High Energy Transient Experiment (HETE) is an astrophysics project funded by NASA and led by the Center for Space Research (CSR) at the Massachusetts Institute of Technology (MIT). It has for principal goal the detection and precise localization of the still mysterious sources of gamma ray bursts.

The project is original in many respects. HETE will provide simultaneous observations of bursts in the gamma, X-ray and UV ranges from the same small (250 lbms) space platform. A network of ground stations around the world will diffuse in real time key information derived from HETE observations to many ground observatories, allowing quick follow-on observations with ground instruments. The whole project is entirely managed by MIT, under top level NASA supervision, and satellite and ground stations will be remotely operated from CSR. The HETE system development is conducted with a small budget and under a short schedule.

HETE scientific goals

The original concept of using a small, low cost anti-sun pointing spacecraft for astrophysics research was initiated by MIT-CSR in a 1987 proposal to NASA, described in reference 1.

The principal mission of HETE is the detection and localization of the sources of astrophysical gamma ray bursts. The gamma ray bursts are high energy events observed as large fluxes of gamma rays in a very wide energy range, and lasting from a few milliseconds to a couple of hundreds of seconds. The sources seem located randomly all over the celestial sphere, and generally do not repeat. The spectra of the bursts extend to the X-ray range, and it is expected that there could be associated UV emissions.

The HETE mission is the localization of the direction of some gamma ray bursts to arc second levels . The spacecraft carries an array of gamma ray detectors, built by the CESR laboratory in France with CNES funding, a wide field X-ray telescope, developed by RIKEN in Japan with a coded mask from the Los Alamos National Laboratory, and four UV cameras built for NASA by MIT-CSR. Figure 1 shows a sketch of the HETE science Instrument package.

Four gamma sensors will detect gamma-ray bursts within 2π sr, in the range of 6kev to more than 1Mev. The gamma sensors will monitor background events, identify and characterize gamma bursts at their onset, and trigger the overall system burst observation modes. During, and a few second prior to the bursts, the system will record the energy and and time-tag every observed event (gamma photon) and those data will be forwarded to the principal ground stations.

The wide field X-ray monitor, using one-dimensional proportional counters and coded masks, will detect and locate events in the 2 to 25 kev range, within a field of about 2 sr, and with an angular resolution of ± 6'.

Four UV transient cameras with an overall field of view of 1.7 sr in the same direction as the X-ray monitor will detect UV transients and locate the sources within ± 6 ". The field of search for the UV events will be narrowed using the indications provided by the X-ray monitor.

The X-ray monitor and the UV cameras will be used to attempt to reduce the error bars on the locations of some bursts, which will hopefully permit the identification of possible astrophysical sources for the gamma ray burst.

Also a small GPS receiver on board, and accurate ranging methods for the spacecraft, will provide excellent accuracy in knowledge of absolute time and position for the observations. That will lead to useful information for data analysis and after-the-fact triangulation of the sources using other data from interplanetary probes.

Initial information such as burst detection, and estimated location as computed by the on-board processors will be broadcasted in VHF to observatories around the world equipped with low cost receive-only HETE ground stations. Whenever possible these observatories will use their ground instruments in search for traces of the bursts at the locations indicated by HETE.

HETE spacecraft

AeroAstro has worked cooperatively with MIT to define the design and the actual spacecraft is now in development at AeroAstro. An isometric drawing of the spacecraft is shown in Figure 1.

Instrument housing and boxes provide the mechanical structure for the spacecraft. Four solar panels, built using carbon fiber structures, are always pointing in the sun direction when on station, and provide power to the spacecraft.

The spacecraft attitude acquisition and deployment follows an automatic sequence after release from the launcher. On station the spacecraft is sun pointing, and stabilized in three axes. The actual orientation of the spacecraft around the sun direction is unspecified. During observations however, that orientation is kept fixed. Attitude control is provided by three torque coils, and one momentum wheel. Fine and coarse sun sensors, and magnetometers provide attitude information. The payload UV cameras are used as accurate star sensors in the control loop to minimize drift rates during observations.

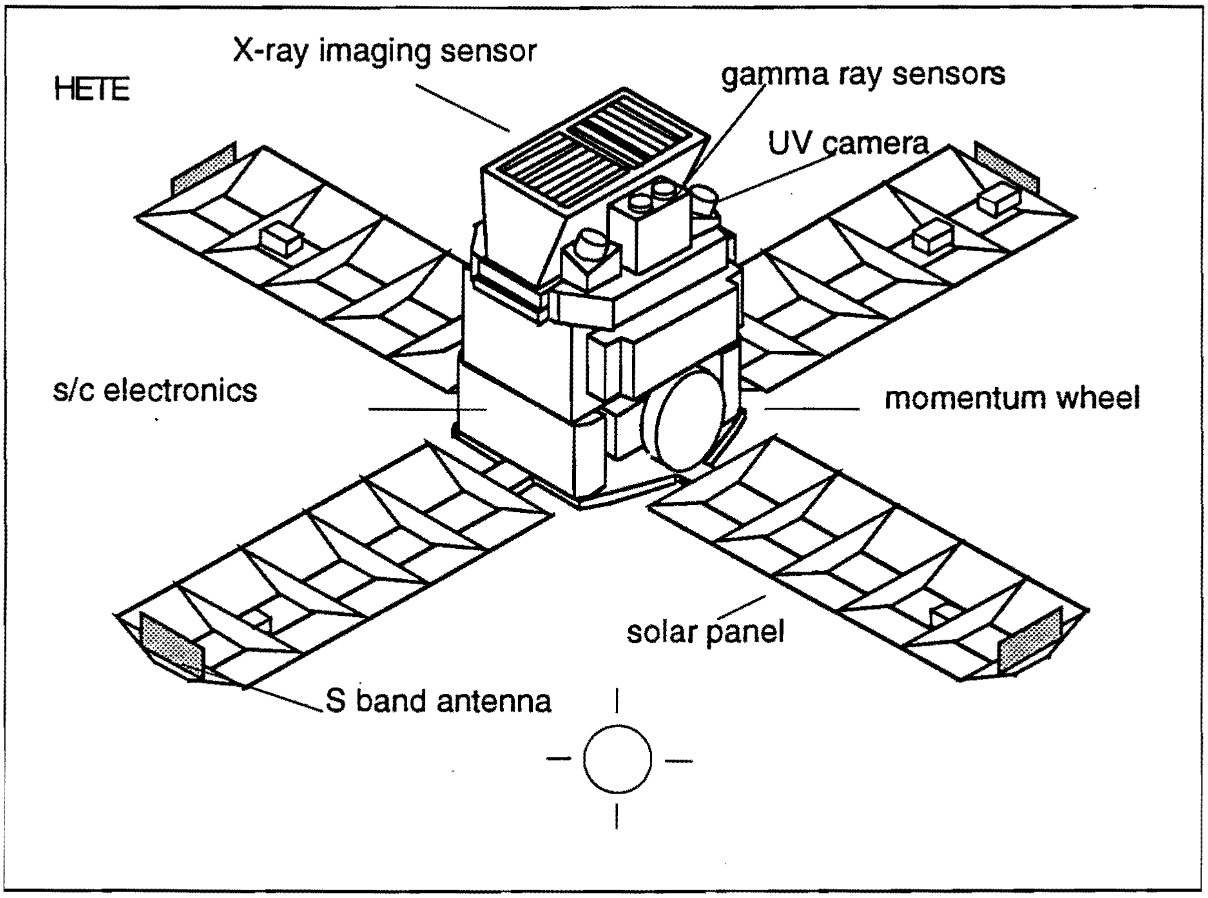

Figure 1. HETE scientific payload is pointed in the anti-solar direction. The spacecraft is stabilized in three axes . The communication system uses the antenna which is in the best orientation at the time of contact with the ground station .

After HETE is deployed in its operational orbit, navigation and timing information are independently acquired by accurate ranging from the three major ground stations, and by an on-board GPS receiver.

The communication system includes an S-band 250 kbit/sec transmitter, a S band receiver, and a VHF 300 bit/sec transmitter. 5 S-band hemispheric antennas are deployed to insure good coverage for any attitude.

The central electronic box includes 12 microprocessors (80 VAX Mips overall power) managing a total of 100 megabytes of memory. The processors are grouped in four divisions servicing the three payload categories and the spacecraft subsystems. The processors are interconnected in an architecture allowing the sharing of tasks. In particular vital tasks can be redistributed allowing graceful degradation of the system instead of catastrophic failure, if a critical processor was to fail.

HETE benefits from many of the technical and organizational lessons learned in the previous ALEXIS program. We have found several avenues to providing "graceful degradation" as an intermediate between no redundancy and fully redundant designs.

The HETE bus is highly integrated with the payload in order to maintain small size and mass with increased capability. This advantage comes with the disadvantage that each payload interface is mechanically more complex. However, electrically each payload element is thought of as a discrete device supported by bus carrier. Thus each experimenter (HETE supports 4 experiment development groups) is supplied with a simple emulator of the HETE digital and power interface, including software, so that most of the development can be completed without the need to travel to the integration facility at AeroAstro.

General specifications for HETE are shown in the table below.

Specification	**Value**	**Unit**	**Comments**
S/C Power	60	W	37 W to payload
Pointing	± 2.0	deg	knowledge to ±0.2°
Drift rates	5"/sec	deg	Orbit night (goal 1.8"/sec)
Total Mass	<109	kg	
Diameter	60	cm	Appr. (TV screen shape)
Height	90	cm	
Data Storage	96	Mbyte	
Data Downlink Rate	230	kbit /s	
Data Uplink / Day	7.5	kbit /s	Software uploads
Data Error Rate	<2e-8	bit /bit	
Spacecraft Lifetime	6	months	Nothing precludes 18 months
Reliability	>95	%	
Workmanship			Best Commercial Practice Mil-P-55110 as a guide
Quality	10	krad	SEU tolerant design, latch-up protection.

Ground System

The HETE ground system consists of three major ground stations, nominally at 120° longitude intervals near latitude 40°, and over 20 receive-only ground stations located at observatories around the world (see Figure 2)

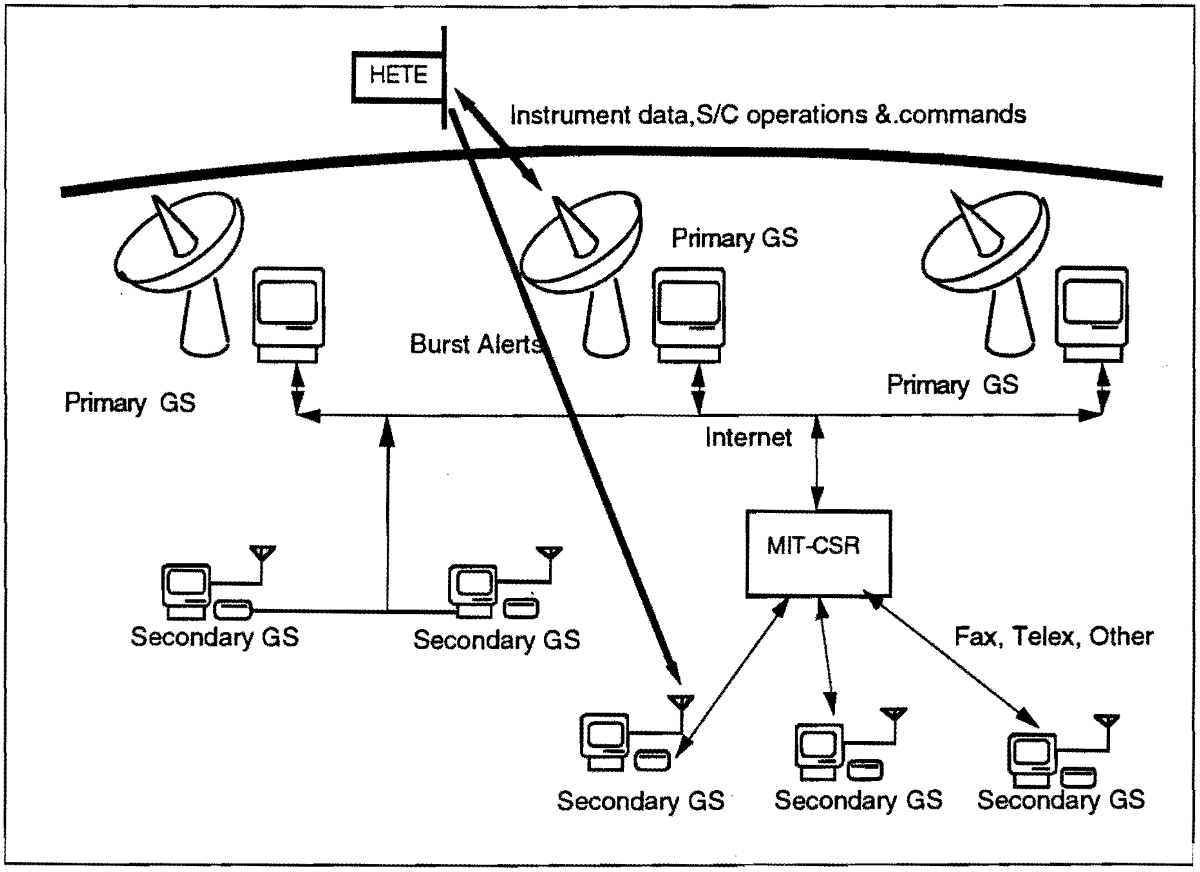

Figure 2. The HETE ground station systems consists of three primary stations controlled via Internet from MIT-CSR, and and array of small secondary stations at observatories around the world to monitor burst alerts.

The three major stations have full capability for command uploading to the platform and data downloading. They will be remotely controlled by MIT using the Internet communication network. In addition HETE will broadcast warning and status signal at low data rates to the small receive-only stations. That will allow the possibility for astronomical observatories around the world to rapidly observe the sky in the direction of bursts detected and located by HETE. This ground station network is in effect a very sophisticated system allowing full control of a powerful astrophysics experiment by an educational and research institution, and permitting extensive international cooperation within research laboratories in many countries.

Project

The project was fully funded by NASA in Spring 1992 as a management experiment and a pilot project for "University Satellites".

MIT is in charge of the whole project development. MIT subcontracts directly to AeroAstro for the platform and ground station systems, and has direct understandings with the collaborating laboratories in France and Japan. NASA management involvement in the project is kept to a minimum, chiefly high level progress monitoring, and launcher interface and safety supervision.

The project is defined by its scientific goals and has a fixed budget and a tight schedule. MIT is responsible for design, manufacturing, testing and operations of the whole HETE system. If difficulties arise affecting budget and/or schedule, they are to be handled if need be by "descoping" the goals. The project is a NASA Class D operation, for which few restrictive specifications apply, except concerning safety. As a consequence the projected costs for the HETE program are low compared to similar "classical" programs.

HETE launch is managed by NASA. The launch is scheduled for December 1994 aboard a Pegasus and along the Argentine solar research satellite, SAC-B.

Summary:

The HETE project is a powerful example of what can be done with a small satellite system. A complete space observatory can be deployed and operated by a small team of researchers within an educational institution, with the support of the small satellite industry. A significant and international space science experiment is conducted at minimal costs to the government, with interesting and rapid scientific and educational returns. The philosophy of the program also allows the use of state of the art technologies, paving the way for their applications in larger programs.

Reference

1. Ricker, G.R. et al 1992, in Gamma-Ray Bursts: Observations, Analyses, and Theories; eds, C.Ho, R.I.Epskin, and E.F.Fenimore (Cambridge University Press, Cambridge UK), pp. 288-296

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