Gamma-ray Large Area Space Telescope
Advanced Technology Development

(GLAST)

Instrument Data Bus
Trade Study

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Advanced Technology Development

Instrument Data Bus
Trade Study

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<table>
<thead>
<tr>
<th>Number</th>
<th>Release</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Basic</td>
<td>December 17, 1998</td>
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<tr>
<td>2</td>
<td>Revision A</td>
<td>February 12, 1999</td>
</tr>
</tbody>
</table>
Contents

1 Scope .......................... 1

2 Purpose .......................... 1

3 Background .......................... 1
   3.1 Problem Statement ....................... 2
   3.2 Decision Required ....................... 2
   3.3 Driving Requirements .................... 2
   3.4 Constraints .......................... 2
   3.5 Alternatives .......................... 2

4 Description of Alternatives ................. 3

5 Analyses and Results ....................... 3

6 Evaluation Table ........................ 4
   6.1 Discussion .......................... 4

7 Conclusion .......................... 5

8 Evaluation Criteria ........................ 5
   8.1 Cost Criteria .......................... 5
   8.2 Mass Criteria .......................... 5
   8.3 Power Criteria .......................... 6
   8.4 Risk Criteria .......................... 6
   8.5 Performance Criteria .................... 6
1 Scope

The scope of this trade study is the Instrument Data Bus (IDB) of the Data Acquisition subsystem of the GLAST instrument.

2 Purpose

The purpose of this document is to capture the history and rationale for decisions made to date on the approach to development of the IDB. The IDB technology is still in the development stage and this document does not present a conclusion as to the technology to be used for the flight instrument.

3 Background

It became evident early on that power is the primary problem in the design of the GLAST DAQ. If ground based systems could be used, with no limitations on power, mass, or radiation tolerance, then the data flow problem could be handled easily with minimal cost.

Each tower supports a tracker (TKR) consisting of 32 layers of 1600 digital 1-bit channels. The TKR utilizes a sparse readout which greatly reduces the load on the DAQ. The average number of hits per tower per event is about 15.

The calorimeter reads out all 160 ADCs for every event before reducing the number of samples passed onward for additional processing. The calorimeter uses 12 bit ADCs and one bit must be added to indicate the gain of the preamp. Therefore, at the tower level, the DAQ must acquire about 2500 bits per event when including overhead, header bits, housekeeping, etc.

GLAST is composed of 25 towers in the baseline design. The peak event rate is expected to be in the range of 20,000 events per second with an average event rate of 1400 per second. The corresponding bit rate into each tower is 50 Mbps peak and 3.5 Mbps average. After level 2 processing (L2T), the number of events which must be passed over the network to a single tower for level 3 (L3T) processing is reduced to 390 per second (1 Mbps). Simulations show that the average number of calorimeter bits per event which must be passed to L3T are only about 30, so the average bit rate transmitted per tower depends largely on the tracker.

The X-band downlink rate is tentatively about 68 Mbps. These data rates indicate that the IDB should be able to support at least 100 Mbps, and preferably more. The higher rates are desirable to increase the communications margin.
3.1 Problem Statement

Identify a data bus technology which can provide data rates of at least 100 Mbps while consuming less than one watt average power. The technology must be radiation tolerant.

3.2 Decision Required

Develop a decision and development path which will result in satisfying the GLAST requirements for the IDB.

3.3 Driving Requirements

- Power less than one watt.
- Radiation tolerant.
- Data rates of 100 Mbps or better

3.4 Constraints

- Affordable development cost.
- Near term availability.
- No single point failure mechanisms, preferably retaining the tower redundancy advantage.
- All electronics contained on the Tower Electronics Modules with no additional hardware other than cabling.

3.5 Alternatives

There are a number of candidate data bus technologies that have been investigated for potential use as the GLAST IDB. Some of these technologies have quickly been set aside because of the apparent lack of parts and support infrastructure. For example, some technologies looked at are only used in research environments. Commercially viable technologies with sufficient speed have been evaluated in terms of power with the approach that we might be able to qualify commercial parts for radiation tolerance. Technologies which have been considered include those given in Table 1.
Table 1: Candidate Technologies for the Instrument Data Bus

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
<th>Power</th>
<th>Redundancy</th>
</tr>
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<tbody>
<tr>
<td>Myrinet</td>
<td>Research network, minimal support</td>
<td>High</td>
<td>Star coupler</td>
</tr>
<tr>
<td>Fibrechannel</td>
<td>Fiber</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Firewire</td>
<td></td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>1553B</td>
<td>Too slow</td>
<td>High</td>
<td>Dual, redundant built in</td>
</tr>
<tr>
<td>IEEE 1394</td>
<td></td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Gigabit Ethernet</td>
<td></td>
<td>High</td>
<td>Simple</td>
</tr>
<tr>
<td>100 Mbps Ethernet</td>
<td></td>
<td>Moderate</td>
<td>Simple</td>
</tr>
<tr>
<td>Fiber Optic Data Bus</td>
<td>Rad-hard version</td>
<td>High</td>
<td>Triple, redundant fibers</td>
</tr>
<tr>
<td>1355 Switched Network</td>
<td>LVDS links</td>
<td>Low</td>
<td>Highest (4 way, 32 links)</td>
</tr>
</tbody>
</table>

4 Description of Alternatives

The alternatives are grouped into several areas:

- power requirement
- data rate as applied to the GLAST DAQ
- redundancy scheme
- radiation tolerance
- cost

5 Analyses and Results

The search for an IDB technology began with the assumption that a local area network topology should be used in order to avoid single point failure problems and cost associated with a separate switcher. The concept for using a switched network where the switches are all at the nodes eliminated the problem of a separate switch unit.
6 Evaluation Table

The advantages of a switched network approach as compared to gigabit fiber optic local area networks are:

- very high level of redundancy with at least four data paths per tower :currently considering 32 links per node
- potential low power implementation using LVDS for physical layer :the availability of a ULPCMOS version of the LVDS device would significantly lower total GLAST instrument power requirements including the IDB network
- reduction of bit rate by one order of magnitude or greater at the link level at the same time that aggregate data rates are increased above the gigabit per second level
- option to implement the node using an FPGA or ASIC

The disadvantages of a switched network approach as compared to gigabit fiber optic local area networks are:

- complicated switching software required in the switch
- more complicated analysis of connectivity and throughput
- higher latency

6.1 Discussion

The disadvantage of a complicated switching software is reduced by the availability of the 1355 protocol and many years of historical development of this technology which is available to aid in the implementation. Although the analysis of connectivity and throughput may be more difficult to perform, it is easy to determine that the aggregate throughput will be greatly increased which increases the margins for data flow throughout the instrument. The higher latency implied by routing packets through multiple nodes as compared to a single fiber optic link is not critical for the GLAST DAQ design. Buffering within the instrument greatly reduces the latency requirement which is in the range of milliseconds under worst case conditions. Because the network traffic is managed, it is possible to reduce the latency by selecting such an operating mode if required, although there is no known requirement for latency below a few milliseconds.
7 Conclusion

The IDB will utilize a switched network design with one node and TBD (32?) links per node. The physical layer will utilize the same LVDS parts used elsewhere in GLAST. During the development process, the initial TEM boards will utilize an Ethernet implementation of the IDB while the switched network development goes on in parallel.

8 Evaluation Criteria

8.1 Cost Criteria

The cost of the IDB depends on several factors:

- Parts cost
- Development cost
- Communications complexity between towers
- Work arounds for limited margins
- Operations costs to work around limited performance
- Integration and test costs

8.2 Mass Criteria

The mass contribution from the IDB is expected to be small. Components to be included in the mass comparison include:

- TEM board space
- Cables and connectors
- Additional units (e.g. switch hubs or star couplers)
- Additional shielding beyond the cabling
- External test connectors
- Interface adapters for communication to the spacecraft
8.3 Power Criteria

Although discussions of power normally address the maximum power consumption for a particular technology, this is not an accurate representation of the problem and can be misleading. In particular, because the number of bits which must be transmitted do not change with bus speed, the comparisons should be performed on the basis of average power. Most technologies can be broken down into a static power component and a dynamic component which depends on the number of bits transmitted. For very high speed technologies, the maximum power may indeed be excessive, but the average power at a given bit rate may actually be less than that required by some slower technology. Consequently, the IDB evaluation must be performed for a given bit rate indicative of the actual expected requirement with marginal power costs noted.

8.4 Risk Criteria

What is the probability that the approach will lead to a flyable technology within the power and performance requirements?

8.5 Performance Criteria

There could be science loss if the IDB does not perform to spec or if the requirements are not adequately stated. This criteria relates to the average data rate for the GLAST application. The data flow for GLAST has very special characteristics which should be used in comparing technologies. For example, all 25 towers acquire data at the same time, the transmission of data to the L3T process tower can be synchronized, and the movement of data files throughout the instrument can be synchronized. Buffering at the tower level reduces the demands on latency which usually can be traded off for throughput.