data per night. They are not yet included in the table due to the uncertainties in their modes of operation. (The last line of the table includes VST output.)

When seen in the perspective of the cumulative data volume, these figures reveal the true dimensions of the facility. Figure 1 shows the estimated amount of data flowing into the VLT Science Archive in the years to come. For comparison, the total volume of the HST Science Archive after 8 years of operations is about half a terabyte in size (see article on "HST On-the-fly recalibration" by Micol et al. in this volume).

M. Albrecht
malbrech@eso.org

Using DVD Technology for Archiving Astronomical Data

B. PIRENNE[1, 2], M. ALBRECHT[1]

[1]ESO/DMD, [2]ESO/ST-ECF

Background

Due to the slow evolution of some astrophysical phenomena, long-term preservation of observations has always been a major concern of observatories around the world. Be it hand-drawings on paper or 19th-century glass-plate photographs, the issue at stake is how to best preserve data for the future generations.

The advent of digital imaging and recording equipment in the second half of this century has provided both more observations and denser data storage media. These media can therefore no longer be read by the human eye. Moreover, with no immediate readability to the unaided eye, digital recordings require specific equipment to decipher their content. If a lot of progress has been made in the past decades to manufacture long-lived data storage media, the same is not true for the reading/writing equipment, quickly reaching obsolescence, and the repair of which is rapidly becoming impossible. This apparent contradiction between durable media and transient reading equipment is easy to understand if one realises that the media is usually "passive" whereas the reading device is always active, with mechanical components.

Archivists must therefore reconsider storage technology every few years: a transposition of the archive content from endangered media to the newest technology has to be undertaken almost every three to five years. Another major factor pushing towards migration of data to new technology is costs: the cost of the new technology compared to the old one often brings savings per unit of volume of up to an order of magnitude and are a strong motivation for migration.

Current Situation

In the case of the ESO/HST Science Archive in Garching, since 1988, three different storage media have been used and migrated from/to: The 2GB LMSI 12″ Optical disk, the 6.4 GB Sony 12″ optical disk and the current 0.64 GB CD-R in juke boxes. The reasons for migrating from one to the other are given in Table 1 below.

We abandoned the 12″ optical disk in favour of the more common 5 1/4″ CD-R for two reasons. On the one hand, CD-R were enjoying an international standard defining the way their content should be laid out (ISO 9660). This was a guarantee of durability and multi-vendor support. On the other hand, the possibility of having all the data on-line in juke boxes was finally an affordable possibility as the cost of juke boxes for 12″ optical disks was prohibitive for our archive system (see right-most column of Table 1). This last reason sealed the fate of hardware compatibility with the HST archive at the ST ScI where the data are still on 12″OD in jukeboxes.

However, now that we have completed the migration to CD-R, we are faced with another concern: the data rate growth. The VLT and HST instruments, soon to be commissioned, will produce several TB worth of raw data per year. We could not practically keep these data using CD-ROMs in juke boxes without making major infrastructure investment in storage buildings!

The solution that addresses the density problem and keeps the advantage of the CD-R technology (direct access medium, cheap juke box capability) is the DVD.

Digital Versatile Disk (DVD)

The DVD technology has been very long to come, heralded as it was by the specialised press for a number of years already. However, various disagreements within the industry and disputes around copyright issues have considerably slowed the introduction of this technology. A few months ago, however, equipment to record one's own media (the DVD-R (see Table 2 for a brief description of the variants) became available. Our archive facility was understandably quick to procure and test the equipment and prepare the necessary software to support the device (from Pioneer Corp.). Even now, little support is available. The DVD-R can only be called such if its file system is compliant with the UDF file system. However, software drivers to support this format for both read and write are hardly available. To our knowl-

TABLE 1: The various data storage technologies used so far at the ESO/ST-ECF Archive Facility. Shaded areas represent the solutions actually implemented.. Units of cost represent an arbitrary monetary unit set to 100 per GB for the most expensive solution.

Medium Name	Reason for choice/migration to	Cost per GB	Cost per GB
		without Juke box	with Juke box
2GB/vol LMSI 12″ optical disk	Direct access, best of technology back then. In sync with ST ScI and HST archive	17	100
6.4GB/vol Sony 12″ optical disk	Direct access, factor of 2–3 cheaper to operate, previous technology difficult to maintain. In sync with ST ScI and HST archive	8	34
0.6GB/vol 5 1/4″ CD-R	Jukebox allows for online, no-operator-required access, ISO standard for file system	0.6	7.8
4.0GB/vol 5 1/4″ DVD-R	Much higher density, keeps direct access advantage of CD-ROMs	2.2	2.8

TABLE 2: The Jungle with acronyms

Acronym	Meaning	Description
CD	Compact Disk	Mass produced (Audio) CD
CD-ROM	Compact Disk - Read-Only Memory	Mass-produced (silver) CD-ROM
CD-R	CD Recordable	Write-once, read-many CD
CD-RW	CD ReWriteable	Re writeable CD-ROM
DVD	Digital Versatile Disk	Mass-reproduced Video medium
DVD-ROM	DVD Read-only Memory	Mass-reproduced data disk 4.7, 9.4, 18.8 GB.
DVD-R	DVD Recordable	recordable DVD (3.95GB)
DVD-RAM	DVD random access memory	re-writeable DVD (2.6 GB)
DVD-RW	DVD re-writeable	re-writeable DVD (??)

edge only the latest version of the MacOS operating system has genuine support for it. The Unix world so far enjoys no support.

In order to obtain quick results and to be as compatible as possible with the existing archive tools and procedures we are using, we took a pragmatic approach: we contacted the developer of a public-domain CD-R recording tool "cdrecord" (a popular Linux tool, see below) and arranged with him to extend his software for the production of DVD-Rs as well. Within a few months, a workable system was delivered to us. However, due to the lack of software support for the DVD native UDF file system, we are using the standard CD-ROM format (650MB ISO9660) extended to 4GB. To the host computer, our "DVD-R" once written simply looks like an unusually large CD-ROM.

Projects and Schedules

The most pressing and demanding project in our archive for high-density storage media at the moment is the future 2.2-m telescope mosaic camera that will be commissioned in La Silla starting this October. If our tests and prototypes, together with juke box support are positive, the DVD technology will be the system of choice for this particular archive. Also, we have started to migrate the NTT archive from the current Sony 12″ optical disks to DVD. By the time this issue of *The Messenger* is distributed, we will have copied a few dozen Sony 12″ optical disks onto the new medium.

We still expect to have full UDF support later in 1999. Our current experience shows that the computer operating system will probably transparently identify and mount media using any of the standards. So the co-existence in the same jukebox of CD-R, DVD-R with ISO9660 and plain DVD-R with UDF should be no problem.

The next step, in 1999 or 2000 will be the gradual migration of our CD-Rs onto the new medium to save jukebox storage space, as this is by far still the largest part of the storage cost of CD-Rs.

For more information about this system, please contact the authors (`bpirenne@eso.org` or `malbrech@eso.org`). Information about "cdrecord″ can be obtained from Jörg Schilling (`schilling@fokus.gmd.de`). The DVD-R recording device we are using is Pioneer model DVR-S101.

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How the Analysis of HST Engineering Telemetry Supports the WFPC2 Association Project and Enhances FOS Calibration Accuracy

M. DOLENSKY, A. MICOL, B. PIRENNE, M. ROSA, ST-ECF

Introduction

The analysis of Hubble Space Telescope (HST) engineering telemetry at STScI is a process that evolved over time since launch in April 1990. Today a jitter file is computed for every dataset by a system called Observatory Monitoring System (OMS). The jitter files, produced to study the telescope pointing stability and the trends in the telescope/instrument performance within the orbital environment, are available for datasets taken after October 1994. These files are supposed to contain sufficient information for an astronomer to properly reduce scientific data.

This has two implications:

1. Jitter files for datasets before October 1994 are either missing or were computed differently.

2. Engineering parameters that are not part of the jitter files cannot be retrieved from the HST archive.

This article shows what kind of problems this can cause, and more importantly, how these problems were solved in case of the WFPC2 Association Project as well as the FOS Post Operational Archive.

Jitter and WFPC2 Associations

ST-ECF embarked on a project aiming at grouping, cosmic-ray cleaning and drizzling images taken by WFPC2 (Wide Field Planetary Camera). Therefore, very precise pointing information is required. The jitter files proved to be the most reliable source of pointing information, with a relative accuracy between two exposures in the same HST visit of about 0.01 arcsec (A. Micol et al. in this issue, related web page \r * MERGEFORMAT [6]). Furthermore, possible pointing instabilities of HST during an observation can be assessed which are sometimes leading to evident perturbation of the PSF (Fig. 2).

ECF's archive interface includes a Java applet that draws X/Y plots of any two columns of a jitter file as seen in Figure 2. This can be done interactively through a common web browser (M. Dolensky et al. in this issue [5]).

Since WFPC2 replaced WFPC in December 1993, it was necessary to