MIGRATION FROM VAX TO MODERN ALPHA COMPUTERS

Klaus R. Nötzel

Deutsche Telekom AG, Forschungs- und Technologiezentrum
P.O. Box 10 00 03, D-64276 Darmstadt, Germany

ABSTRACT

Deutsche Telekom has been operating different communication satellites for several years. The Satellite Control Center (SCC) of Deutsche Telekom is located near Usingen, about 50 km northwest of Frankfurt/Main. The system has been under operation since the launch of the first flight model DFS in June 1989. The entire computer system was based on Digital Equipment Corporation (DEC) VAX type computers. The maintenance costs of these old Complex Instruction Sets Computers (CISC) were increased significantly during the last years. Due to the high operational costs Deutsche Telekom decided to exchange the operational computer system. Present-day information technology world uses more and more powerful Reduced Instruction Set Computers (RISC). These new designs allow operational costs to be reduced appreciably. The VAX type computers will be replaced by DEC Alpha AXP Computers. This paper describes the transition process from CISC to RISC computers in an operational realtime environment.

KEYWORDS

Satellite Control Center, Digital Equipment Corporation (DEC) Computers, VAX, Alpha AXP, operational costs, system design, MOTIF

INTRODUCTION

The Satellite Control Center (SCC) of DBP Telekom is located near Usingen, about 50 km northwest of Frankfurt/Main. The system has been under operation since the launch of the first flight model DFS in June 1989. The Ku-band acquisition of TV-Sat was performed in August 1989, the acquisition of DFS 2 in July 1990. In 1992, the system was expanded for the operation of DFS 3, which was launched in September 1992. The Launch and Early Orbit Phase (LEOP) was supported by Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR).
Besides the SCC, the earth station also has communication facilities for Eutelsat satellites as well as for the Intelsat satellites over the Atlantic and Indian Oceans. The SCC is composed of the spacecraft control facilities and the necessary ground stations at different locations. The SCC provides all necessary features for simultaneous and continuous operation for four satellites, with expansion capability for two further spacecraft.

The Satellite Control Center of DBP Telekom is composed of

- two control rooms
- the main computers
- the offline analysis system (OAMS)
- the flight dynamic system (FDS)
- the baseband equipment installed in the central building
- the antenna buildings for DFS and TV-Sat with RF-equipment and the antennas.
- network interconnections to
  - EUMETSAT at Darmstadt
  - German Space Operation Center (GSOC) of Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR) including the remote ground stations at DLR sites (S- and Ku-bands).

The system configuration of the Satellite Control Center is shown in Figure 1.

The system is distributed over several rooms and buildings. A redundant Ethernet based Local Area Network (LAN) with standard protocols is used for interconnection of the equipment.

**COMPUTER SYSTEMS HARDWARE DESIGN AND NETWORKING**

The old computer system is mainly based on Digital Equipment Corporation (DEC) hardware. The operating system is VMS. The system is equipped with a mid-size cluster system and workstation computers. The flight dynamic system uses workstations from Hewlett Packard (HP). The entire system runs 24 hours a day, 7 days a week. Figure 2 shows a diagram of the computer systems.

The first computers of the old system were VAX 11/750, dated 1986. New versions of the application and operating system software had reduced margins in system performance. The last upgrade of the station computer (STC) was to a dual CPU VAX 8350 cluster system. In the following the system is described in detail.
Figure 1. Configuration of the SCC

Station computers: Three VAX 8350 computers in a cluster configuration with one starcoupler (CI-cluster). Two VAX units in master/back-up configuration process data in real time, the third unit is in standby as cold redundancy.

Hard-disk system: Access to the diskfarm is controlled by two redundant HSC storage controllers for common use of storage devices.

Workstations: Are used for processing and displaying primary real-time data. The processed output of the workstations is displayed by thirty X.11-window terminals in the control rooms.

LAN Network: Two physical Ethernet channels take over communication between all computers in the SCC. Redundancy switching of the LAN is performed by the STC and is transparent to the users. Two network protocols are used, DECNet (between DEC Computers) and TCP/IP between computers of different vendors. For external data communication Wide Area Network (WAN) routers are used. These routers perform also security checks for communication outside Telekom SCC.
Communications: Data links are installed between Telekom SCC, DLR GSOC, DLR Weilheim and EUMETSAT Control Center (Darmstadt). Data communications is carried by ISDN (Integrated Services Digital Network) and leased lines.

Figure 2. Overview of entire computer system

WHY OPENVMS AND NOT UNIX

The entire operational software must be rewritten for DEC Alpha AXP. More and more open UNIX systems are used all over the world. This fact lead to a study of using an UNIX operating system instead of OpenVMS. Arguments against UNIX were:

- No compatibility with the old data archive, which must be supported for 10 years
- Personnel must be retrained for UNIX
- The cluster environment with its high availability is not available
- Costs for porting the software to UNIX are higher than porting from VAX to Alpha AXP
- Compatibility with the DLR GSOC control center will be lost
Finally, the cost aspects of porting the software and the necessary training for UNIX systems lead to the solution of using DEC Alpha AXP systems with OpenVMS as operating system.

Figure 3. Overview of the old computer system

ADVANTAGES AND DISADVANTAGES OF THE DEC ALPHA ARCHITECTURE

Current computer technology uses mainly two different architectures: Complex Instruction Set Computers (CISC) and Reduced Instruction Set Computers (RISC). VAX is a CISC, Alpha a RISC architecture. The basic differences between both architectures are shown in Table 1.

The hardware design of the Alpha processors allows operation of different operating systems on one machine (OpenVMS, DEC UNIC, WINDOWS NT). That means, to use another operating system, normally only the new operating system has to be installed. The hardware itself supports different operating systems.

Alpha computers use a 4-byte fixed length data format. Data that do not fullfill this requirement can be converted, but this conversion needs up to 20 times more CPU time than the same instruction executed on a VAX system.

These circumstances may lead to a entirely new design of the software implementation.
<table>
<thead>
<tr>
<th></th>
<th>VAX (CISC)</th>
<th>Alpha (RISC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
<td>CISC</td>
<td>RISC</td>
</tr>
<tr>
<td>Instruction format</td>
<td>complex variable length</td>
<td>simple fixed length</td>
</tr>
<tr>
<td>Addressing mode numbers</td>
<td>large</td>
<td>small</td>
</tr>
<tr>
<td>Size of registers</td>
<td>small-to-medium</td>
<td>large</td>
</tr>
<tr>
<td>Instruction set model</td>
<td>register-to-memory</td>
<td>load-store</td>
</tr>
<tr>
<td>Execution of instructions</td>
<td>micro-coded</td>
<td>direct in hardware</td>
</tr>
<tr>
<td>Virtual address range</td>
<td>32 bits</td>
<td>max. 64 bits</td>
</tr>
<tr>
<td>Physical address range</td>
<td>max. 32 bits</td>
<td>max. 48 bits</td>
</tr>
<tr>
<td>Page size</td>
<td>512 bytes</td>
<td>8KB - 64 KB</td>
</tr>
<tr>
<td>Instruction length</td>
<td>1 - 51 bytes</td>
<td>4 bytes</td>
</tr>
<tr>
<td>General registers</td>
<td>16 x 32 bits</td>
<td>64 x 64 bits</td>
</tr>
<tr>
<td>Addressing modes</td>
<td>21</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1. Architectural differences

NETWORKING

One of the major requirements for the new system was, that it must be compatible with the existing hardware and software. The telemetry and telecommand baseband is equipped with PDP11 computers running DECnet Phase IV. A wide variety of protocols is used at the Usingen SCC:

- DECnet Phase IV
- DECnet Phase V only for Wide Area Network (WAN) routers to external partners
- TCP/IP between all other systems (HP UNIX, PC’s)

The network protocol compatibility will be ensured by different DEC network products:

- DECnet Phase IV for OpenVMS AXP
- DECnet Phase V for OpenVMS AXP
- TCP/IP services, server and client (also known as UCX) for OpenVMS AXP

COMPATIBILITY ASPECTS

The real-time VAX computers only will be replaced. All other systems, baseband and computers, must remain and work properly together with the new Alpha AXP computers.
The new system must be compatible with all the other software and hardware interfaces as

- Realtime interface to the baseband equipment
- Monitoring and control interfaces
- Remote control centers and ground station

The range of the remaining computer systems varies from DEC PDP11, DEC VAX 11/750 over DEC MicroVAX and Hewlett Packard UNIX workstations to DEC VAX stations. The entire data generated at the SCC like telemetry, telecommand, monitor and control information are stored on 8 mm Exabyte tapes. These old tapes must be readable by the new system.

The new archiving software supports the old file formats and new more efficient storage formats.

**DESIGN OF THE NEW SYSTEM**

The new system is also based on a DEC cluster environment. The CI - cluster environment was not available for PCI Bus based machines, the cluster is built via a DSSI bus. Three servers with the same performance form the main station computer. The cluster configuration itself is formed by two servers and a quorum disk. The third server will work as

- Emergency stand-alone system if the cluster is not available or
- Third cluster member in a LAN based (LAVC) configuration.

![Diagram of new AXP system](image)

*Figure 4. Layout of new AXP system*
The new high performance disk system is a Microtechnology RAID system. The RAID system is directly connected to the dual DSSI bus. If one cluster machine is not available the remaining computer has still access to the information. Even the emergency system has access through the LAVC cluster configuration.

The RAID system is configured with RAID Level 5. This configuration allows failure of one disk drive without impact on normal operation.

The RAID array itself is formed by five 4.3 GByte drives. The overhead for parity information is around 20 %. The old shadow set configuration had an overhead of 100 %.

If the failed drive is replaced, the system will rebuild the information on that disk with data- and parity information spread over the remaining four disks. Once started, this process is transparent to the user.

The RAID system allows a Hot-Swap of devices like single disk drives, power supplies and StingRay® DSSI controllers. These devices are user-changeable, an extended service contract which covers more than normal working hours is not necessary.

The raw computing power of the new system is a nearly 100-fold increase, compared with the old one. Table 2 shows a comparison between both systems.

<table>
<thead>
<tr>
<th></th>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating System</td>
<td>OpenVMS VAX</td>
<td>OpenVMS AXP</td>
</tr>
<tr>
<td>Station computer</td>
<td>3 * VAX 8350</td>
<td>2 * AlphaServer 2000/233</td>
</tr>
<tr>
<td>No. of CPUs</td>
<td>2 of 2 possible</td>
<td>1 of 2 possible</td>
</tr>
<tr>
<td>Memory</td>
<td>32 MByte</td>
<td>128 MByte</td>
</tr>
<tr>
<td>Performance</td>
<td>2.3 VUP (SPECint92: ~ 2.3)</td>
<td>SPECint92: 177, SPECfp92: 215</td>
</tr>
<tr>
<td>Disk system</td>
<td>6 * RA 90 with HSC 50</td>
<td>MTI StorageWare RAID</td>
</tr>
<tr>
<td>Controller</td>
<td>HSC 50</td>
<td>Stingray DSSI redundant</td>
</tr>
<tr>
<td>Configuration</td>
<td>Shadow set</td>
<td>RAID level 5</td>
</tr>
<tr>
<td>Capacity</td>
<td>3,6 GByte</td>
<td>17,2 GByte</td>
</tr>
<tr>
<td>Workstations</td>
<td>6 * µVAX 3200</td>
<td>6 * AlphaStation 200 4/233</td>
</tr>
<tr>
<td>Disk capacity</td>
<td>2 * 154 MByte</td>
<td>2 * 2 GByte</td>
</tr>
<tr>
<td>Performance</td>
<td>2.4 VUP (SPECint92: ~ 2.3)</td>
<td>SPECint92: 157, SPECfp92: 183</td>
</tr>
<tr>
<td>Windowing software</td>
<td>DEC VWS</td>
<td>DEC MOTIF</td>
</tr>
<tr>
<td>Emergency System</td>
<td>µVAX 3100</td>
<td>AlphaServer 2000/233</td>
</tr>
<tr>
<td>Memory</td>
<td>32 MByte</td>
<td>128 MByte</td>
</tr>
<tr>
<td>Disk capacity</td>
<td>2 * 500 MByte</td>
<td>2 * 2 GByte</td>
</tr>
<tr>
<td>Performance</td>
<td>3.5 VUP (SPECint92: ~ 3.5)</td>
<td>SPECint92: 177, SPECfp92: 215</td>
</tr>
</tbody>
</table>

Table 2. Performance Comparison

NEW USER INTERFACES

The old user interface was based on colour character oriented terminals (DEC VT 340). Figure 5 shows an example of a new display format.
The old character based interface will be still available. New display formats will only be implemented for the new system. The new system provides a modern window oriented graphical user interface (GUI). The GUI uses a MOTIF application on standard X-window terminals. The interface application is built by commercial off-the-shelf products (TeleUse, Sphinx). The new GUI is a very flexible tool. The user can easily create and add new display pages. Dynamic symbols can be created to visualize the status of systems or devices by different colours or graphic elements.

OPERATIONAL COSTS

The old computer system is based on technology of the year 1986. The costs for maintainence contracts are increasing every year. Many old components are no longer available. Not in each case is it possible to use the new “compatible” components, e.g. problems with networks cards were detected. The new system comes with a three-year warranty, which means that there no additional costs will arise for maintance in the first three years of operation. The operational costs for the old system were so high that the break-even point for the new system will be reached within 30 months. This includes all hardware and software.
OPERATIONAL TRANSITION FROM THE OLD TO THE NEW SYSTEM

Satellite control is a mission critical application. The operational switch-over from the old to the new system is planned to take place in two steps.

• First, the final acceptance of the new system must be successful. Both systems will be fully operational in parallel for two months. This time is necessary to identify hidden errors and non documented features.
• Second, after a period of thirty days with no or only minor failures operations will be switched to the new system. Only the old emergency system will be kept for back-up purposes.

The new system will be fully operational by the end of 1996.

REFERENCES