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FROM: J. H. Saltzer
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Multics system initialization has been completely redesigned since October, 1966, when the previous overview was published. Enclosed is a new overview, BL.0, which describes the new design. The major improvement in the design is that the file system paging mechanism is initialized very early, so that it may be used during the remainder of initialization.

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Identification

Overview of the Multics System Initialization
A. Bensoussan

Purpose

This section provides an overview of the various steps taken in initializing Multics.

Introduction

The various initialization segments as well as the segments that will comprise the hardcore supervisor of Multics are all stored on a single magnetic tape known as the Multics System Tape (MST).

From the time the bootload button is pushed to the time Multics is initialized, 3 different stages are to be distinguished, corresponding to 3 programs of different nature:

1. The bootload program
2. The bootstrap initializer
3. The Multics initializer

The bootload program is a special program in this sense that it is located in the GIOC diodes and therefore it is part of the 645 hardware. Furthermore, it is executed in absolute mode.

The bootstrap initializer is a higher level program; although it is entered in absolute mode, its first worry is to set up a descriptor segment and to institute the appending mode. However, it is still a "handicapped" program since it does not tolerate any fault; as a consequence it cannot use the standard call-save-return macros.

As for the Multics initializer, it can be coded like a normal Multics program, using the call-save-return macros, the dynamic linkage, the dynamic core allocation following a missing page fault, and the dynamic descriptor segment fabrication following the missing segment fault. The

linkage, missing page and missing segment fault handlers have been made available by the bootstrap initializer; they are not, of course, the standard Multics handlers but they perform the functions expected by the Multics initializer programmer. It is precisely one of the most important Multics initializer's duties to make the Multics handlers available for the above mentioned faults.

Having justified the existence of the 3 stages by the different nature of the programs that comprise them, we give below a brief description of each stage.

The bootload program

The GIOC contains, in fixed storage, 64 words which are transferred into selected locations in core memory when a button (known as the "bootload button") is pushed. The 64 words are stored in the GIOC in a form of a diode matrix and the base of the locations in core into which they are transferred is determined by panel switches on the system control console. As soon as the 64 words are read into core, an interrupt is sent to the processor which services interrupts on this GIOC. The interrupt transfers the processor to the base of the block into which the 64 words have been stored. This processor is the only processor which will be executing during most of the initialization sequence.

The diode matrix contains the "bootload program". The bootload program is expecting a tape to be ready on the tape handler connected to channel 31, device 0. If for some reason, channel 31 is not available, any other channel connected to a tape handler can be used; in this case, the channel number has to be made known by the operator to the bootload program through the 36 bit processor switches as described in BC.4.01. Furthermore, the bootload program is designed to read a tape written in the Multics standard format (BB.3.01); briefly, any information recorded on a Multics tape has in front of it a "label" that ends with an end of file physical record.

When entered, the bootload program takes the following actions:

1. It skips the label until the end of file physical record is encountered.

2. It reads into core the next physical record.

3. It transfers to the loaded program at a conventional entry point, passing interface information through index registers.

The bootload program is designed to read any Multics tape provided that it satisfies the entry point convention; this tape may contain the Multics system or any dump or diagnostic program. For this reason, the bootload program is not documented in BL sections (initialization) but rather in BC sections (hardware).

In our case, the tape is the Multics system tape; therefore, the bootload program loads the portion of the bootstrap initializer contained in the first physical record following the label and transfers to its entry point.

The bootstrap initializer

The bootstrap initializer is the interface between the bootload program and the Multics initializer. As the reader will notice, the Multics initializer is a very large program which has an impressive number of functions to perform. Therefore, "he" positively refuses to do any work in the poor environment left behind the bootload program. "He" wants "somebody" to load and initialize a few of "his" segments; that is the sine qua non condition for "him" to be able to work. "Somebody", of course, is the bootstrap initializer. Therefore, the bootstrap initializer starts reading the rest of itself, then it reads and initializes the few segments mentioned above, whereby providing the Multics initializer with:

1. An initialized descriptor segment

2. Paired base address registers, according to the Multics standard convention so that call-save-return macro can be used.

3. A loader, known as the "segment loader", that is capable, with the help of its utility routines, of loading segments from the MST

4. A fault handling mechanism such that

   a. When a linkage fault occurs, the fault can be replaced by the correct machine address, if the referenced segment is in core

   b. When a missing page fault occurs memory is dynamically allocated

   c. When a missing segment fault occurs, an appropriate segment descriptor word and the page table are manufactured.

The first instructions of bootstrap initializer execute in absolute mode and they create a descriptor segment. From this point on, all the stages of the initialization can execute using the appending hardware.

For each segment that it reads from the MST, the bootstrap initializer creates a segment descriptor word that is appended to the descriptor segment, and an entry in a segment known as the "Segment Loading Table" (SLT). In this statement, three important objects have been mentioned: the MST, the descriptor segment and the SLT; some comments would be wise at this point.

The MST contains all the segments that need to be loaded during Multics initialization: the initialization segments, as well as the segments that comprise the hardcore supervisor, as well as the segments that comprise the basic file system hierarchy in case the hierarchy must be reloaded. Each of these segments recorded on the MST, whether it is a "text" or "link" segment, is preceded by an additional piece of information: its "header". This header contains, among other things, the name of the segment, its current length, its maximum length, its access right, its status, the page size, its type (initialization segment or supervisor segment), etc. Briefly it contains anything that might be needed at any point of the initialization.

The SLT is the segment in which all the headers recorded on the MST will be saved during initialization. Each time a segment is to be loaded from the MST, its header is loaded first, since it precedes the segment; this header is used to manufacture a fixed length entry for the segment in the SLT. Therefore, the SLT contains an entry for each initialization or hardware supervisor segment which are currently known during system initialization. Creating an SLT entry for a segment implies assigning to it a segment number because the SLT is indexable by segment number. After the SLT entry is created, a segment descriptor word has to be built in the descriptor segment.

The descriptor segment created by the bootstrap initializer will be used throughout the rest of system initialization. The structure chosen for the descriptor segment is based on the following remark: There is no reason why hardcore supervisor segments should have different segment numbers during Multics initialization and during Multics operation. Therefore, in the descriptor segment, segment numbers 0 to n are reserved for hardcore supervisor segments while segment numbers greater than n are reserved for initialization segments. This structure gives the following advantages: first, as far as the linkage mechanism is concerned, any hardcore supervisor which has been "prelinked" can still be used by the Multics initializer; second, when all the hardcore supervisor segments have been loaded from the MST, the upper part of the descriptor segment is the "template" descriptor segment used at process creation time.

When the set of segments needed by the Multics initializer to be able to stand alone have been loaded and initialized, the bootstrap initializer calls the Multics initializer's main program known as "Initializer Control Program", using a standard call macro instruction, since it now is available.

The Multics initializer

It is in fact at this stage that the whole initialization takes place. The purpose of the two previous stages, bootload program and bootstrap initializer, was merely to provide the Multics initializer with the minimum machinery needed for being able to run alone properly.

The Multics initializer is basically concerned with the following functions: It makes known the hardware configuration, initializes the secondary storage devices, loads and pre-links the hardcore supervisor, initializes per-system data bases, initializes per-process segments, and per-process entries in the system tables in such a way that the Multics initializer becomes a Multics process, and it creates the necessary system processes so that Multics can stand alone. Then it passes control to the Multics system control, that is no more part of the Multics initializer.

1. Make known the hardware configuration. The hardware configuration is described in several segments that are recorded on the MST. Let us assume that K segments are needed. Call each of these segments CONF.SEG(k) where k=0,1,...K. The names of these segments are given in a loadlist, which is also a segment. Call this loadlist segment CONF.LL. At the time the Multics system tape is created, the desired configuration may not be known; therefore, the MST contains a description for a certain number I of possible configurations. For a given configuration CONF(i), the loadlist CONF.LL(i) contains the names of the K(i) segments needed to describe this configuration. Call each of the segments CONF.SEG(i,k) where k=1,2,...k(i). In the MST, the information is organized into "collections". A collection is a logical file. All the segments CONF.LL(i), for i=1,2,...I, are contained in the same collection, the "configuration loadlists" collection. All the segments CONF.SEG(i,k), for i=1,2,..,I and k=1,2,...K(i) are contained in the next collection, the "configuration library" collection.

   The Multics initializer is able to interact with the operator during initialization. It first asks the configuration number i; then it loads the corresponding configuration loadlist CONF.LL(i) and asks the operator if he wants to update it; the loadlist is changed according to the operator's requests and every segment whose name appears in the configuration loadlist is loaded from the configuration library collection. Then the operator has the ability of changing the content of any CONF.SEG(i,k) segment that has been loaded. When this is done, using the content of all the segments CONF.SEG(i,k) that have been loaded (and eventually updated), the Multics initializer builds the system configuration table.

2. Initialize secondary storage. If the file system hierarchy must be reloaded, free storage maps are written on all secondary storage devices available to the file system. Then, areas of secondary storage to be used by this version of Multics are defined, the root directory is initialized and the segments needed to operate the hierarchy reconstruction process are loaded in secondary storage.

3. Load the hardcore supervisor. Like the configuration segments, the hardcore supervisor segments are mentioned in a loadlist. The MST may contain a certain number J of hardcore supervisor versions. For a given supervisor version SUP(j), the loadlist SUP.LL(j) contains the names of the K(j) segments that make up this supervisor version. Call each of these segments SUP.SEG(j,k) where k=1,2,...,K(j). In the MST, all the segments SUP.LL(j), for j=1,2,...,J, are in the "supervisor loadlists" collection. All the segments SUP.SEG(j,k), for j=1,2,...,J and k=1,2,...,K(j) are contained in the "supervisor library" collection.

   The operator is asked for the number j of the supervisor version he wants. The Multics initializer loads the corresponding supervisor loadlist SUP.LL(j). Then the operator is asked if he wants to update it; the loadlist is changed according to his requests. Then every segment SUP.SEG(j,k) whose name appears in the SUP.LL(j) segment (eventually updated) is loaded from the supervisor collection library. The operator does not have the ability of requesting to change any of the segments loaded from the library collection.

4. Prelink the hardcore supervisor. In the hardcore ring of the Multics supervisor, dynamic linking is not a necessary feature, since all modules to be used in any single version of the hardcore supervisor are known at initialization time. Thus, a dynamic link and search mechanism will accomplish nothing that pre-linking at initialization time cannot do. Since in addition the majority of all processes share the same copies of virtually all data and procedure segments of the hard-core ring, pre-linking these data and procedure segments permits the linkage sections themselves to be shared also. Prelinking therefore has two purposes:

1) The Multics dynamic linking and search mechanism does not have to be a part of the hardcore ring, and does not have to be "wired down", and

2) The number of per/process segments is reduced.

5. Initialize per-system data bases. They are:

   a. The file system data bases: the core map, the hardcore segment table (HST), the device disposition table (DDT), the data bases (buffers, DIM history) of each device interface module (DIM), the active segment table (AST), the descriptor segment table (DST), the process segment table (PST), the process waiting table (PWT).

   b. The traffic controller data bases: the known process table (KPT), the active process table (APT), a processor data segment for each processor, the template descriptor segment, stack history.

   c. The fault-interrupt interceptors data bases: the fault interrupt vector, the vector redirector segment, the system communication segment, the processor communication segment.

   d. The I/O system data bases: GIOC interface module (GIM) data bases, tape controller interface module (TCIM) data bases.

   Although it is not an exhaustive list of the system data bases, this list contains the major system data bases that have to be initialized.

6. Initialize per process data bases. A Multics process is characterized by 5 basic segments that are created in the process creation module. These segments are: process directory, known segment table, process data segment, process definition segment and hardcore stack. They must be created and initialized on the behalf of the Multics initializer.

7. Create per-process entries in system data bases. An entry for the Multics initializer process is created in the known process table (KPT), in the active process table (APT) and in the process segment table (PST). One entry is created in the descriptor segment table (DST) for the descriptor segment of the Multics initializer. An active file trailer (AFT) is associated with every AST entry, showing that the corresponding segment is active on the behalf of the Multics initializer.

8. Create one branch for each existing segment in the appropriate subtree of the hierarchy.

9. Create necessary system processes. When the functions described above have been done, the Multics initializer presents all the characteristics of a Multics process, with the only restriction that it is the only process in the system and therefore it cannot afford to be blocked. In order to negate this restriction, necessary system processes are created, using the standard process creation mechanism. The system processes to be created by the Multics initializer are specified in the system configuration table. They can be for instance the file system device monitor process, an idle process assigned to a processor, etc.

At this point the Multics initializer is a full active and loaded Multics process. The work assigned to it is completed and the Multics initializer issues a call to the system control procedure:

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call <Multics> | [system_control].
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When this call is given, the Multics initializer evolves into the System Control Process, and Multics is now "in operation". The system control process creates the other members of the system control process-group; then it creates the answering service process to allow Multics users to "dial-up" the computer.

Note that the system control is not part of the Multics initializer. It is documented in BQ section.

After having read this paragraph, the Multics initializer might appear to be a straightforward program, with 9 independent modules to perform the 9 functions mentioned. The main disadvantage of this approach is that it would require a large amount of special purpose code to perform functions that can be done automatically by the hardcore supervisor. Therefore the strategy that has been chosen, which is described in BL.5.00, is basically as follows: A group of hardcore supervisor segments is loaded and initialized; then another group of hardcore supervisor segments is loaded, and it is initialized using the hardcore supervisor segments made available previously and so on.

The second disadvantage of the straightforward method is that it would require to have in core, at the same time, all the hardcore supervisor segments even if they do not need to be wired down when Multics is operating. For the present time, the size of the hardcore supervisor is such that this requirement cannot be satisfied. In the strategy that has been taken, only the wired-down segments of the hardcore supervisor need to be in core at the same time during Multics initialization.

Identification of a Multics System

When a Multics System is initialized it is identified by three items:

1. Tape identification
2. Configuration identification
3. Supervisor identification

The tape identification (TI) is a unique name recorded on the Multics system tape when it is created, for example "MAC23"

The configuration identification (CI) is the name of the configuration loadlist selected by the operator, for example, "18"

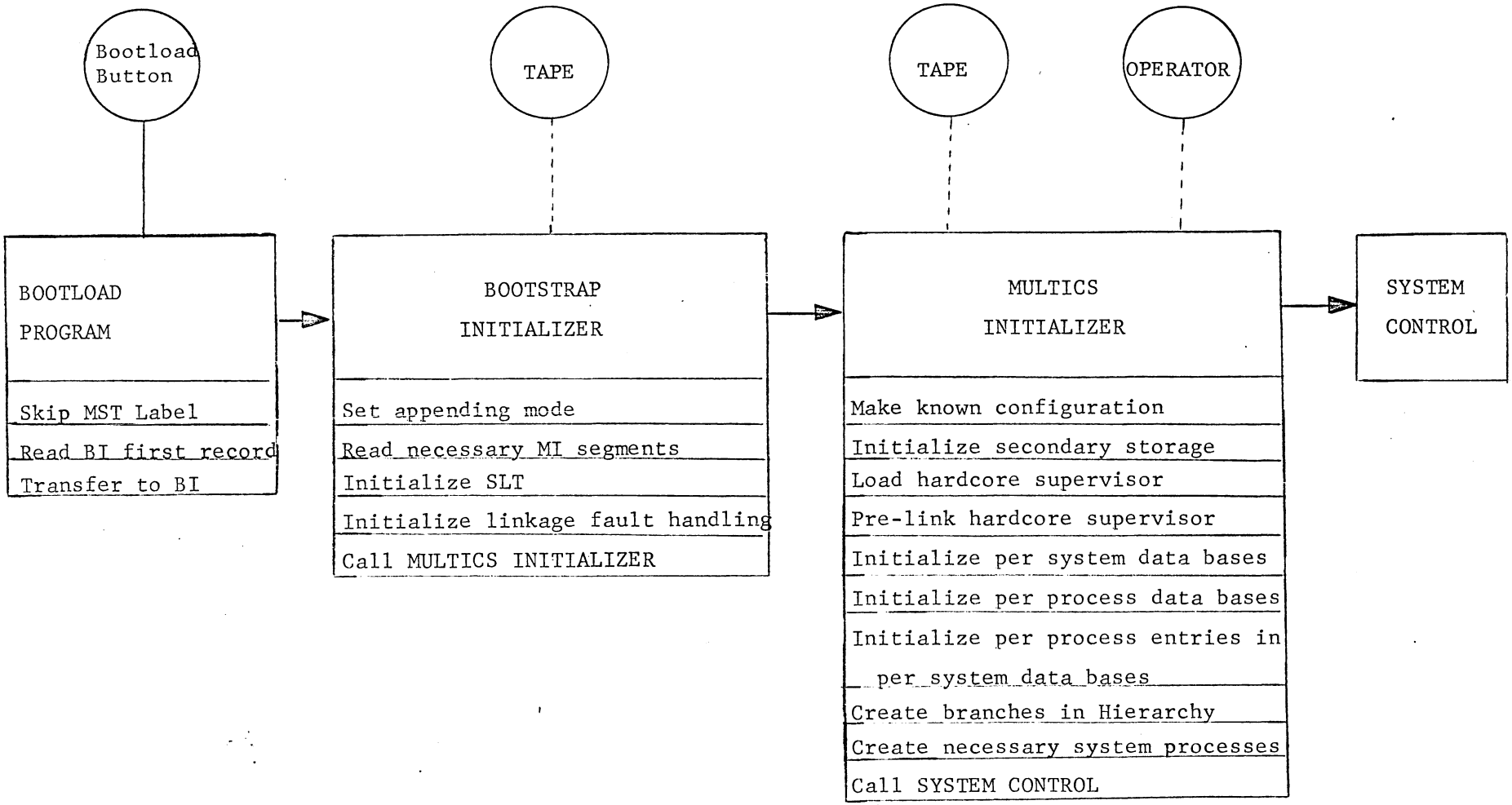
The supervisor identification (SI) is the name of the supervisor loadlist selected by the operator, for example "L"

A typical system identification might then be MAC23.18.L

If operator editing of the configuration list or load list has occurred, a "single quote" (prime) character is appended to the appropriate part of the system identification, e.g., MAC23.18'.L

Organization of BL sections

As it can be noticed, the first stage "bootload program" is not part of BL sections. It is documented as part of the hardware, in BC.4.01. All the data bases used by the "bootstrap initializer" and by the Multics initialize itself: the MST, the SLT and the system configuration table are grouped at the beginning of the BL chapter under BL.1,2 and 3. BL.4 is the bootstrap initializer. BL.5 is the Multics initializer. The point this paragraph wants to make is that sections BL.6,7,8,9,10 and 11 have to be thought of as BL.5 subsections since the modules they describe: segment loader, initialization linker, I/O initializer, fault-interrupt initializer, file system initializer and traffic controller initializer, are part of the Multics initializer.


Bootload Button
TAPE
TAPE
OPERATOR
BOOTLOAD PROGRAM
Skip MST Label
Read BI first record
Transfer to BI
BOOTSTRAP INITIALIZER
Set appending mode
Read necessary MI segments
Initialize SLT
Initialize linkage fault handling
Call MULTICS INITIALIZER
MULTICS INITIALIZER
Make known configuration
Initialize secondary storage
Load hardcore supervisor
Pre-link hardcore supervisor
Initialize per system data bases
Initialize per process data bases
Initialize per process entries in per system data bases
Create branches in Hierarchy
Create necessary system processes
Call SYSTEM CONTROL
SYSTEM CONTROL