

DRAFT:

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Identification

Resource Reservation Overview

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Purpose:

The purpose of resource reservation is the effective use of resources through pre-scheduling. It is not to be concluded that all the resources of a Multics installation must be reserved. In some instances very little of the total resource would be reserved. The Transactor through its resource reservation facility provides for the reserving of resources when it is necessary or desirable.

Discussion:

There are two valid reasons for reserving Multics resources. First, a job requires resources (such as tape drives) which are to be used by only that job. Secondly, a job must be done at a specific time or must be finished by a specific time.

The first reason gives rise to a distinction between resource types, those which can be reasonably shared by more than one user (e.g. processor) and those which must be dedicated for efficient utilization (tape drive). If a job required dedicated resources, it must make a reservation for these and any other resources required during the same period.

In the second instance, the Transactor is asked to commit the system to a specific completion time or execution period. In order to make such a commitment the required resources, regardless of their nature, must be pre-scheduled. An example of such a job is a group demonstration.

As was stated earlier, not all the resources of a Multics installation are reservable. Those resources or parts thereof, which are to be managed by the Transactor are administratively decided upon as a function of the installation's needs and desires. A specific Multics installation may decide to provide for reservation of 12 of its 16 tape drives and 50% of the total processor capacity, using the remaining 50% to handle other demands. At another installation it might be desirable to manage shareable resources, such as the processor, in a different manner so that the reservable percentage varies as a function of time of day. For example, the Transactor might accept reservations for processing time for 10% of the processing capability from 0800-1800, 20% from 1800 to 2400 and 50% from 0000 to 0800. The actual distribution would, of course, be determined by each Multics installation.

Streams of resource service may be defined by individual installations

which desire to provide users with a degraded service at a reduced rate. These streams provide an alternative to the user who wishes to submit an absentee job but does not need a reservation. Only processor resource service streams are considered and therefore jobs requiring only processor time (including the Basic File System) may request stream service. In general, a stream provides degraded service (from the standpoint of turn-around) rather than improved service. For example, a Multics installation may choose to provide three streams of processor service x, y, and z in addition to those streams of processor available for reservation and that used for the interactive load. Stream x is serviced by 10% of the processor from 2A.M. to 4A.M. every day at a rate of 80% the standard rate. Stream y is serviced by 5% of the processor at all times unless it is needed to fulfill reservations or supplement that part of the processor used to handle the interactive load and therefore is not guaranteed to be available all the time. This stream might be charged at 75% the standard rate. Stream z becomes active only when all other streams are inactive that is, no other work to be done. Its rate might be 60% of the standard rate.

Each stream is controlled by an absentee monitor process, and not by any part of the Transactor. The process is responsible for initiation and termination of jobs in the stream queue. See B0.1.05 for a description of absentee monitor processes.

Usage:

The usage of the reservation system of the Transactor requires that some information be provided so that the resource reservation can be made. A user may be as general or as detailed in his reservation specification as he wishes.

The Transactor recognizes five types of input related to resource reserving.

- 1) A time interval. This establishes the interval of time within which the reservation should be made.
- 2) A shared-resource time. This establishes the amount of a shared resource capability which is desired during the time interval. It will normally indicate the amount of processing time needed to support the use of dedicated resources. It is valid to reserve only shared resource time without dedicated resources.
- 3) A dedicated-resource time. This establishes the length of time for which dedicated resources (#4) are to be reserved within the time interval. This time is the same for all the dedicated resources reserved for one job.
- 4) Resources. This establishes the number and types of resources which should be reserved for a job. Only if he has proper authority is a user allowed to specify a particular device unit. The particular resource strategies are discussed in BT.2.

- 5) Additional Reservation Specifications. These inform the Transactor of any special handling it should initiate as a part of the reservation. The kind of information which might be included here is that special paper is needed on the line printer. Another possibility is that specific tape reel is to be used on a tape drive and is to be known by a certain unique identification. If the reservation can be rescheduled to an earlier time without notifying the requester, this characteristic is noted here.

The Command Language provides a mechanism by which an argument of the command may be a procedure. Users of the Transactor commands may wish to use this feature when specifying a reservation; for example, in reserving resources for a tape sort/merge, it is sometimes very difficult to express a reservation in terms of resources required since several alternatives are available. In this case, a procedure could be invoked which, when given the sort/merge criteria, produces the reservation criteria for the Transactor.

The Transactor utilizes whatever information (of the five types) in offered to it and attempts to make the requested reservation. If there are inconsistencies or if vital information is left out, it asks for clarification. If non-vital information is left out, the user is reminded that it is possible to supply that information.

A reservation of time, specified in input types 2 and 3, is regarded as a limit stop. The user is allowed to use any amount of time on a resource up to and including the amount specified. A reservation of space, specified in input type 4, is regarded as a constraint. The user must have at least (usually, exactly) that amount of that is, space on a resource. For example, reserving three tape drives and 100 blocks of core for one hour means that the user want exactly three tape drives and at least 100 blocks of core for some amount of time less than or equal to one hour.

If the Transactor is unable to reserve as requested, the user is told which of his requirements could not be met. If all requirements can be met, the reservation is tentatively made for the earliest possible time within the interval and the user is informed of the time. At this point the user is given a fixed interval of time in which to accept or reject the reservation. If no action is taken by the user, the tentative reservation is cancelled.

All reservations should be regarded as expected times rather than as promised times. Clearly, situations can arise in which it is impossible to honor a reservation. Hopefully, these will be infrequent and reservations will be honored. Since reservation of some dedicated resources may require operator action such as the mounting of a tape, some interval (depending on the complexity of the possible actions) is always added to the front of every reservation on those resources to allow for the operator's actions. This added resource time is not charged as part of the reservation.

From the standpoint of resource reservation, Multics serves two basic

user types. The most common type of user is one who does not require the reservation of resources and is free to use the system at any time, load conditions permitting. This type user is not the concern of the resource reservation facility of the Transactor. A user who does have resource reservation requirements is also served by Multics and negotiates with the Transactor for resource reservations.

The reservation interval requested falls into one of two reservation periods. The primary reservation period extends from time "now" to some future time. If the interval requested falls within the primary reservation period, the reservation can be confirmed by the Transactor immediately and is accepted or rejected by the user. The time period beyond t, is called the secondary reservation period. Reservations for the secondary reservation period are recorded by the Transactor and will be confirmed later if they do not conflict with a previous reservation request or a planned reservation. The user will be informed by "mail" of the success or failure of the reservation.

A user may qualify his reservation as being a moveable reservation and that a time interval is not specified. The Transactor is free to dynamically move this reservation and to fill in gaps in the reservation schedules due to premature logouts or cancellations. There is no commitment on behalf of Multics regarding this type reservation, and therefore, it is considered to be a lower grade of service at a reduced rate. By its very nature, a job holding such a reservation is capable of being processed at any time and does not require that the user be present during its execution (the user is absentee). Many of the so-called batch processing jobs requiring resources are of this nature.

The job which makes use of the planned reservation facility falls into a class referred to as the cyclic job. It is run periodically at a fixed frequency requiring fixed resources. An example of this type job is the weekly payroll. Reservations for jobs of this type are given first consideration in that for a given time interval (day, week, month) these reservations are made first before others are considered.

It is quite possible that conflicts may arise among planned reservations due to cycle differences. For example, month end accounting reports may at some time conflict with the weekly payroll. These conflicts are not resolved by the Transactor. The system administrator is informed of the conflicts and must take positive action to resolve them. Other reservations will not be made until all these conflicts have been resolved and all planned reservations have been confirmed.

The following are some examples of how specific Multics users make use of the resource reservation facility. The examples assume that the interval requested is within the primary reservation period.

Interactive

This Multics user requiring the use of reserved resources wishes to interact with the process during execution. Sometime prior to his desired re-

servations he logs in and specifies the reservation requirements. The Transactor attempts to make a coordinated reservation so that the shared resources are reserved during the period that the dedicated resources are reserved and the total reservation is within the interval requested. If successful, the user will be informed, at which time he must accept or reject the reservation. If unsuccessful, the user will also be notified and the earliest possible commitment will be relayed to the user. He must then accept or reject this reservation within a certain fixed time. At an appropriate time prior to the reservation, the operations personnel are informed of their duties (if any) regarding this reservation. Since it is possible that circumstances are such that operator duties cannot be completed (e.g., specific tape reel not available) the operators must always respond, positively or negatively, as to the completion of duties.

Sometimes prior to the required time, the user signals by command that he is ready to keep his reservation. If, at the required time, all has proceeded well, he begins to interact with his process. At resource release time (either an explicit release or a logout) the dedicated resources become available for further reservation.

If the operators are unable to complete their duties regarding this reservation, the user is informed that his reservation was cancelled and the reason is given.

Absentee

This Multics user requires the use of reserved resources, but does not intend to be present during the running of his processes. He proceeds in the same manner as the interactive user except that he prepares or designates files to be used as input and output when the process is awakened, and declares himself absentee, thus establishing a user with no remote terminal.

Responsibilities

Responsibilities fall into two categories, user responsibility and Transactor responsibility.

After a reservation has been made for a user and he has accepted it, he is considered responsible for it. He may cancel the reservation prior to the reserved period. No charge will be made if the cancellation occurs within a reasonable amount of time before the reservation period. What constitutes a reasonable amount of time varies between installations and is almost certainly a function of what resources were reserved. If the cancellation occurs after this time, the user is liable for the resources which he reserved and which cannot be rescheduled.

When the Transactor receives a reservation request, it first checks the authority of the user. Inadequate authority causes the reservation to

be refused. If the user has adequate authority, his allotment of system resources is checked. If the user's allotment is more than sufficient to cover the reservation, a part of his allotment equal of the cost of the reservation is placed in a newly-created reservation account. Controls are placed on the reservation account such that the proper amount of the allotment is spent on each part of the reservation. Accounting charges the cost incurred by the reservation to the newly-established reservation account.

If the user's allotment is not sufficient or is marginal, he is warned that he should attempt to increase his allotment. He is also told that his account (or some other account which he is allowed to use) must provide an allotment sufficient to cover the reservation by a certain time prior to the reservation. Failure in this respect results in cancellation of the reservation. If the condition is met, a reservation account is created. The time when the sufficient funds must be available is the same as the reasonable time before which a user may cancel a reservation without penalty. In both cases, the time is installation and resource-type dependent.

As implied earlier, the Transactor has further responsibilities as the reservation approaches. If a resource requires operator attention before it can be ready, the Transactor must alert the operator to the need. If the user specified any additional special handling (such as tape reels) the Transactor must inform the operator of this. The Transactor must also alert the I/O System as to the device assignments made by the Transactor.

Authorities

The reservation of resources is very critical in that it involves the commitment of funds. It is therefore necessary to establish the authority of the person attempting a reservation of resources.

The types of authority are as follows and appear in the user's profile. The following order does not imply importance.

- 1) None - This class of user cannot reserve any resource.
- 2) Some resources - This class of user can reserve a specific resource or resources, e.g., processor, but nothing else.
- 3) All resources - This user can freely reserve all resources.
- 4) Special - This user has the authority to reserve specific units of resources, e.g., tape drive A. A produce serviceman has this type authority.

It is essential that the Transactor prepare an audit trail of all transactions associated with reserving resources. This audit trail is kept in a file accessible to the system administrator and any designated individuals. These records are kept for a period of time to be determined

by each Multics installation. The audit trail is used for validating complaints, recovering in the event of system crash, determining system load and statistical analysis in general.

Implementation

The resource reservation functions of the Transactor are implemented as commands, system processes and procedure segments within the user process. The resource reservation procedures are invoked by command or are called as a part of system processes. Figure 1 will prove helpful in following the implementation description.

Reservation Coordination Procedure

The reservation coordination procedure attempts to reserve the specific resources by calling the appropriate resource reservation procedure. If all resources requested are free for reservation within the limits provided by the user, its duties consist only of informing the user that the reservation is possible and requesting his acceptance.

If even a single resource is not available for the specified criteria, its function becomes considerably more complex. It attempts to provide the user with the earliest possible time that all the resources are available simultaneously.

Having made a reservation, the reservation coordination procedure determines if there is a need for scheduling instructions to operations personnel. If this is the case, an alarm clock wakeup is scheduled for the operator process. In any event, a wakeup is scheduled for the connection process. All reservations that are accepted are given a reservation number by the reservation coordination procedure which must be presented when keeping the reservation or making changes such as a cancellation.

Resource Reservation Procedure

Resource reservation procedures are responsible for reservations of a specific device or class of devices. They are called by the reservation coordination procedure which provides as input the interval, the resource time, the required quantity of this type resource, and the reservation number assigned by the reservation coordinator procedure.

A resource reservation procedure will attempt to make the reservation as specified by consulting the appropriate resource schedule. If successful, the caller is informed. If unsuccessful, and "earliest possible" reservation is tentatively made and the caller is informed. If unsatisfactory, the caller rejects this reservation. As implied above, each resource reservation procedure must have an entry point for cancelling a reservation. When cancelling part of a reservation, the reservation number and device quantity to be cancelled must be specified.

Each resource reservation procedure accesses resource schedule data bases which contain the agreed-upon reservations for this resource type. There is a one-to-one correspondence between a resource schedule and a physical resource. This should not be interpreted as meaning that a permanent physical assignment is done at reservation time. Physical assignment is done immediately prior to the beginning of the reservation by the operator process or the connection process and forwarded to the I/O system by the connection process.

In some cases, reservation does imply assignment; for example, a reservation of a printer in a one printer system. In other cases, such as a bank of identical magnetic tapes, the reservations are kept as though physically assigned to a specific drive but at assignment time may actually be shifted to another free identical resource in the event the scheduled device is not available. This scheme is used to accommodate that user whose authority is such that he can specify a specific device; for example, the product serviceman.

Take, for example, a system containing five tape drives designated physically A,B,C,D,E. A resource schedule is maintained for each drive. Consider a reservation requiring 3 drives starting at time t for 2 hours. If, A,B, & C are selected for this reservation and at time t physical drive A is not available, the reservation can still be honored if either drive D or E is available. On the other hand, the product serviceman can request drive A for 2 hours at time t and be sure of getting drive A and not any other one of the five drives.

Operator Process

This process is awakened by alarm clock set by the resource coordination procedure and is responsible for issuing instructions to the various operators. It does this by consulting the reservation schedule, issuing all operator instructions indicated. The operator process demands a response from the operator as to the successful or unsuccessful completion of a task.

It is possible that due to unforeseen difficulties, the operators are not able to complete the operating instructions (e.g., can't find tape reel X99). In this event, the operator informs the operator process and the reservation is cancelled. The reason for cancellation is noted in the user "mailbox" and the user is informed when his process is awakened.

Core Allocation Process

This process is much like the operations process except that it makes requests for core from core control, specifying the amount of core to be transferred to a pool which core control will use to satisfy the core requirements of processes associated with this user.

Keep-Reservation Procedure

This procedure is invoked by command and must have as arguments the reservation number and the name of the working process to be awakened. Given this information, the keep-reservation procedure will consult the reservation data base and store the working process id in the entry for the reservation with the designated reservation number so that the working process can be awakened. It is important that this command be executed before the reservation period. If executed late the reservation is forfeited and the user must negotiate for a new reservation.

Connection Process

This system process is awakened by an alarm clock which was set by a reservation command. All entries in the reservation data base which are due at this time are determined. It makes the call to the I/O system informing it of the physical assignments made by the operator process. The connection process then wakes up the designated working process whose id was stored by the keep-reservation procedure.

Resource Release Procedure

This procedure is executed as part of the user's working process. It accepts calls from logout and other procedures to release (make available for further reservation) reserved resources. A call from logout would indicate release of all resources reserved by the user.

In the event that a user is forced to logout prematurely, the resource release procedure determines if sufficient time is remaining of the reservation to warrant awakening the Early Processing Candidate Process so that it might attempt to fill the unused reservation time.

Early Processing Candidate Process

This system process will attempt to fill the gaps in the reservation schedule which might arise due to premature logout or reservation cancellation. When awakened, it attempts to find a candidate for the vacated period by searching a thread in the reservation schedule data base attempting to fit the reservations which have been indicated as being candidates for early processing into this time period. This is done by making calls to make-reservation with a starting limit equal to the time of the current reservation. If a suitable fit is found, the old reservation is cancelled and the new one accepted. This process then goes to sleep.

Reservations which can be considered for early processing (moveable reservations) must be indicated as a part of the additional reservation specifications at the time a reservation is made.

Reservation Update Process

When the reservation update process awakens, the following types of reservation exist in the reservation schedule. In a time interval from time "now" to a future time t_1 (the primary reservation period), there are confirmed reservations. From time t_1 to another future time t_2 there are planned reservations which are now considered confirmed and other recorded but unconfirmed reservations. From time t_2 to time t_3 there are recorded planned reservations and other recorded but unconfirmed reservations.

The reservation update process first attempts to confirm the recorded reservations for the interval t_1 to t_2 . Users are notified through the mail facility of Multics of the success or failure of this confirmation. If successful these reservations are considered accepted by the user and do not require positive indication. A dissatisfied user may cancel a reservation later.

The second function of the reservation update process is to confirm the recorded planned reservations for the period t_2 to t_3 . Conflicts are referred to a system administrator for resolution. The system administrator must resolve any conflicts before the next scheduled wakeup of the reservation update process. Conflicting reservations are not confirmed by the Transactor.

Having performed these functions, the reservation update process opens the interval t_1 to t_2 for further confirming of reservations, makes arrangements to be awakened and goes to sleep. The primary reservation period now becomes the interval from time "now" to t_2 .

Reservation Data Base

The reservation data base is ordered as a function of increasing time. The reservations in the primary reservation period have been confirmed and will be satisfied barring any unforeseen difficulties. The reservations in the secondary reservation period will be confirmed if they do not conflict with a planned reservation or with one another. The boundary between the two periods is moved ahead by the planned reservation process every time it wakes up.

Early Processing Candidate Table

This table is simply a separately threaded subset of the reservation data base. These reservations are a class of reservation which may be rescheduled by the Transactor without notifying the user.

Planned Reservation Data Base

The planned reservation data base contains all the planned reservations presently considered by the planned reservation process. Each entry, in addition to the normal reservation information, contains the frequency with which this reservation is to be made and the date of the last confirmed reservation.

Resource Schedules

Each Multics resource has a schedule associated with it which reflects the times for which this particular resource has been reserved. These schedules are consulted by the resource reservation procedures whenever a reservation request is to be satisfied. Each schedule contains a pointer to the appropriate entry in the reservation data base and is pointed at by the reservation data base. The resource schedule for the processor reflects the various streams of service provided by this resource.

Make reservation period

Prior to reservation period

reservation period

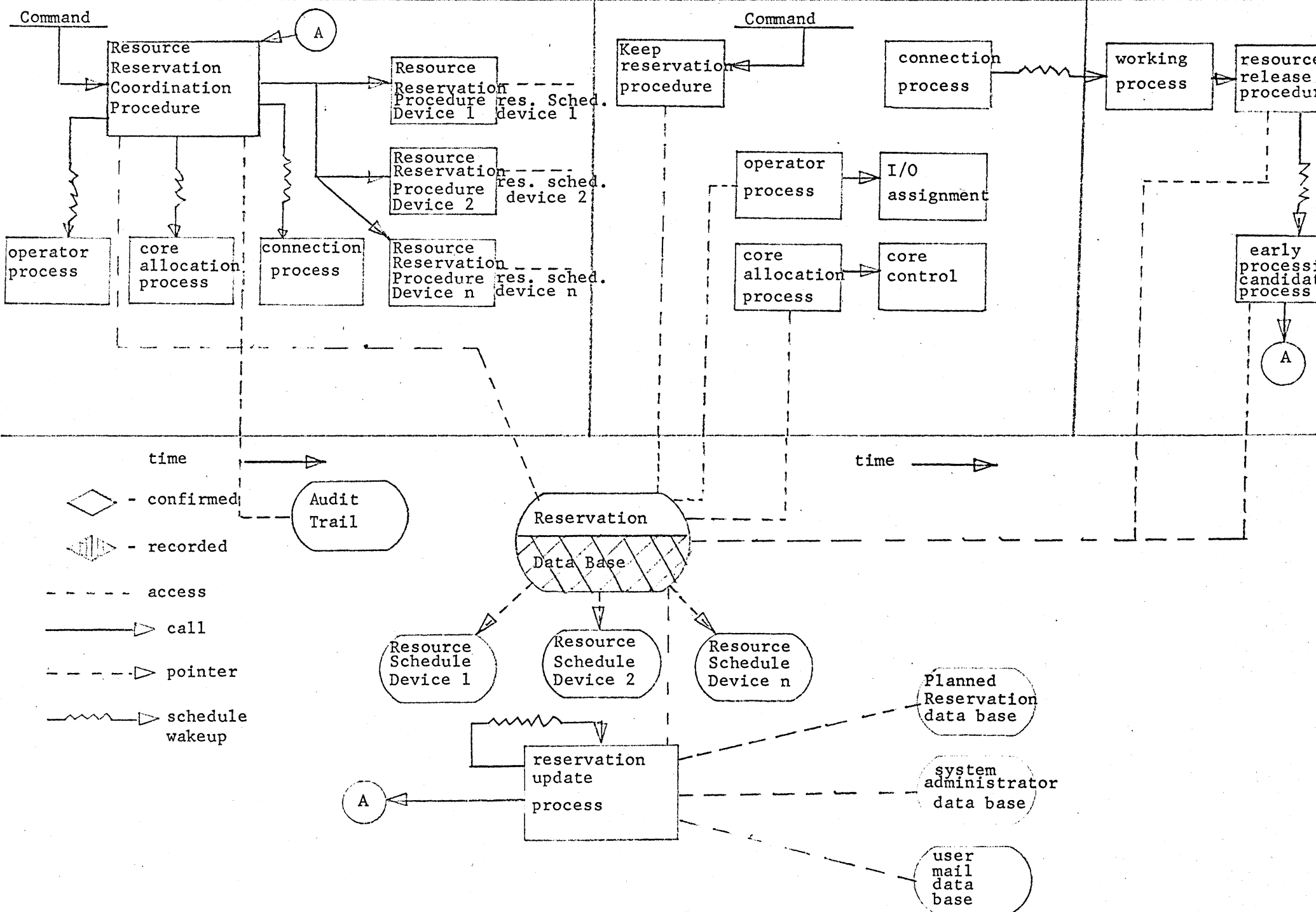


Figure 1