PROJECT MAC

September 5, 1973

Computer Systems Research Division

Request for Comments No. 37

# A CENSUS OF RING 0

by Victor L. Voydock

## Introduction

A major research area of the Computer Systems Research Group is to investigate the problem of producing a certifiable computer operating system. The first approach to this problem could have been to attempt to audit the Multics ring 0 supervisor as it then existed. That is, to read all of the programs which comprised the ring 0 supervisor and determine whether or not they did what they were supposed to do. It was clear that this was not a practical approach due to the size and complexity of ring 0 and the lack of a precise (or even imprecise) specification of its functions.

An approach which immediately suggested itself was to simplify ring 0 so that it could be audited. Before this could be done in any organized way it was necessary to have a clearer idea of what was in ring 0, so it was decided to take a census of ring 0. This document reports the results of that census.

## Approaches

The census analyzes ring 0 from various points of view:

1. A notebook of ring 0 interfaces.
2. A functional breakdown of hcs_ entries.
3. A functional breakdown of all ring 0 segments.
4. A breakdown of all ring 0 segments by source language.

The notebook of interfaces describes every way that ring 0 can be entered by means of a call. It is a first (albeit crude) attempt to provide a functional specification of ring 0. It is available for study to anyone who is interested. The functional breakdown of hcs_ entries will be described in a later RFC. The rest of this document deals with approaches 3 and 4.

## Method of Census Taking

The information in Tables I-VI was gathered from the two directories which contain copies of all ring 0 object segments: >ldd>hard>bc and >ldd>hard>o. The information describes system 20.10a, a 6180 system installed on 8/15/73. The text section sizes were obtained from the object maps. The segment count indicates the number of separately translated pℓ1 and ALM segments. The entry point count includes segdefs, as well as standard entry points. Thus this count is slightly inaccurate since a few procedure segments (such as the FIM) have data segdefs imbedded in them. (There is no way to distinguish a data segdef from a procedure entry point segdef.) The translator names were obtained from the object segments using object_info_.

The functional categories (a complete list appears in Table II) are somewhat arbitrary. Any attempt to put labels on things is bound to distort reality somewhat. Comments on major classification flaws are welcome.

Most of the categories are self-explanatory. (Table VI has a list of all segments in each category.) Physical Storage Management consists of everything which is used to manage the physical storage of segments (core control, page control, bulk store control, etc.). Error Handling and Tracing contains all error handlers not local to one major category (e.g. syserr, verify_lock). Major categories are listed in Table I. Utility (Internal) contains utility segments which are not local to one major category (e.g. privileged_mode_ut). Utility (Shared with other rings) contains utility programs which are also used by rings other than zero (e.g. clock_, signal_, pℓ1_operators_). Obsolete contains segments which exist only for compatibility (either with other parts of the system or with user programs), and transfer vectors which can be thrown away when the appropriate procedures are converted to version 2 pℓ1. All obsolete segments can (eventually) be removed from ring 0 without affecting users.

## General Observations

Finally, some general observations should be made.

First, ring 0 is much smaller than expected - about 157,000 words of text section (executable code and read only data). A large but not monstrous amount of code. For example, the bare bones of the pℓ1 compiler (parse, semantic translator and code generator) take up 118,000 words of text and this figure more than doubles if pℓ1 IO, the file manager and the pℓ1 runtime library are included. Why then is ring 0 so complex and hard to understand? Another measure of complexity is the number of distinct functional units - procedure entry points in pℓ1 terminology. Ring 0 contains 1201 entry points. (The bare bones pℓ1 compiler in contrast, contains 325 entry points.) A large number of entry points can be a symptom rather than a cause of complexity (when it is either) - reducing the number of entry points will not necessarily result in a simpler system. But, nevertheless, an investigation should be made to determine why there are so many entry points and to what extent they contribute to the complexity of ring 0. This investigation might provide insight into how the system might be more simply organized.

The second observation is that the amount of assembly language generated code in ring 0 is larger than expected. 12.4% of non-obsolete ring 0 procedure text is ALM generated. If one views pℓ1_operators_ as an extension of every object segment and excludes it from the total, the figure drops to about 10%. This is still quite high. If, as a very rough estimate, one assumes an average of 5 words of text section per pℓ1 source statement, our results indicate (see Table IV) that ring 0 consists of about 29,000 lines of pℓ1 source and about 15,000 lines of ALM source.

Fortunately, the amount of ALM can probably be reduced significantly. All 64 non-obsolete ALM procedure segments in ring 0 (see Table V), have less than 2000 words of text section each and all but 9 have less than 400 words of text section each. A cursory study has uncovered 13 segments which can be immediately converted to pℓ1 with no loss of system efficiency and additional study will undoubtably uncover others. Dave Reed is currently investigating this area.

Finally, Tables I, II and VI suggest a number of areas in which simplification might yield a significant reduction in the size of ring 0:

initialization - One of the oldest parts of the system. Can probably be reorganized and simplified

salvager - Its size indicates that either it is a collection of ad hoc methods or that the system data bases are not well organized with respect to salvagability.

tty dim and ARPA network - Duplicate functions should be merged. An investigation should also be made into why the ttydim is so large.

interrupt handling - Rich Feiertag's work on simplifying the way interrupts are handled should greatly reduce the complexity, if not the size of the IO system and of Physical Storage Management.

linker, search rules - Phil Jansen's work on removing the linker from ring 0 will remove a complicated function from ring 0 but will not greatly reduce the size of ring 0 (about 3%).

## A Final Comment

Through the use of binding, the actual number of free standing procedure segments in ring 0 is 50 (instead of 305), and the number of accessible entry points is 909 (instead of 1201). A more judicious choice of binding might further reduce the number of accessible entires. Some accessible entries implement primitives used by outer rings and some functional areas span more than one segment. Nevertheless, the number of accessible entires is a rough measure of the connectivity of the various functional areas of ring 0. A study of the interrelations of the 50 free standing procedure segments may lead to insights into the overall structure of ring 0.

Table I: Breakdown by Major Categories (System 20.10a)

| Category | % of total | Words of text section | Number of segments | Number of entries |
|---|---|---|---|---|
| File System/Virtual Memory | 36.7 | 57727 | 93 | 476 |
| Initialization/Reconfiguation/ Shutdown | 15.4 | 24312 | 56 | 102 |
| IO System | 15. | 23602 | 33 | 117 |
| ARPA Network | 12.1 | 19143 | 34 | 158 |
| Utility | 9. | 14269 | 38 | 122 |
| Obsolete | 5.3 | 8400 | 16 | 71 |
| Process Management | 5. | 7809 | 26 | 95 |
| Interrupt/Fault Dispatching | 1.2 | 1966 | 8 | 59 |
| Other (Put in ring 0 for no good reason.) | .2 | 353 | 1 | 1 |
| Total | | 157581 | 305 | 1201 |
| Total (minus obsolete) | | 149181 | 289 | 1130 |

Table II: More Detailed Breakdown
(System 20.10a)

| Category | Words of text section | Number of segments | Number of entries |
|---|---|---|---|
| I. File System/Virtual Memory | 57727 | 93 | 476 |
| A. File System | 18111 | 24 | 125 |
| B. Salvager | 11840 | 15 | 41 |
| C. Linker/Search Rules/ Working Directory | 4572 | 11 | 30 |
| D. Segment Control | 7069 | 13 | 29 |
| E. Physical Storage Management | 11719 | 21 | 209 |
| F. Other (Things which overlap categories) | 4416 | 9 | 42 |
| II. Initialization/Reconfiguration/Shutdown | 24312 | 56 | 102 |
| A. Initialization/Shutdown | 19501 | 46 | 81 |
| B. Reconfiguration | 3207 | 4 | 7 |
| C. Other (Things which overlap categories) | 1604 | 6 | 14 |
| III. IO System | 23602 | 33 | 117 |
| A. IOM/355 | 4533 | 13 | 38 |
| B. Typewriter Control | 11558 | 7 | 25 |
| C. IOAM | 2963 | 6 | 31 |
| D. Printer Control | 2247 | 4 | 9 |
| E. Tape Control | 2301 | 3 | 14 |
| IV. ARPA Network | 19143 | 34 | 158 |
| V. Utility | 14269 | 37 | 122 |
| A. Error Handling and Tracing | 3431 | 11 | 28 |
| B. Utility (Internal) | 1923 | 7 | 41 |
| C. Utility (Shared with other rings) | 8915 | 20 | 53 |
| VI. Obsolete | 8400 | 17 | 71 |
| VII. Process Management | 7809 | 26 | 95 |
| A. Process Creation/Status/ Destruction | 4655 | 19 | 32 |
| B. Inter-Process Communication | 836 | 2 | 11 |
| C. Traffic Control | 1943 | 2 | 40 |
| D. Timers/ips masking | 375 | 3 | 12 |
| VIII. Interrupt/Fault Dispatching | 1966 | 8 | 59 |

Table III: Breakdown by Bound Segment

(System 20.10a)

| Bound Segment Name | Words of text section | Words of linkage section | Number of entries |
|---|---|---|---|
| bound_355_wired | 1640 | 48 | 13 |
| bound_active_1 | 1136 | 96 | 12 |
| bound_error_active | 1232 | 104 | 6 |
| bound_error_wired | 1104 | 96 | 14 |
| bound_file_system | 22984 | 696 | 116 |
| bound_gim_active | 2208 | 112 | 14 |
| bound_init_1 | 2272 | 304 | 14 |
| bound_init_2 | 3264 | 200 | 7 |
| bound_io_init | 2248 | 144 | 5 |
| bound_iom_active | 6568 | 216 | 40 |
| bound_iom_imp_dim_ | 7384 | 376 | 38 |
| bound_iom_imp_status | 4320 | 328 | 23 |
| bound_iom_wired | 6920 | 440 | 29 |
| bound_mseg_prim | 1624 | 88 | 7 |
| bound_network0_ | 8192 | 720 | 26 |
| bound_page_control | 9552 | 328 | 73 |
| bound_process_creation | 7320 | 416 | 27 |
| bound_salvager | 11432 | 344 | 35 |
| bound_sss_active_ | 4832 | 88 | 43 |
| bound_sss_wired_ | 3536 | 24 | 18 |
| bound_system_faults | 19128 | 616 | 111 |
| bound_tc_wired | 1432 | 168 | 16 |
| bound_temp_1 | 6928 | 272 | 17 |
| bound_temp_2 | 648 | 104 | 5 |
| bound_tty_active | 7600 | 136 | 21 |

Table IV: Breakdown by Language
(System 20.10a)

| Category | % of ALM | Words of Text ALM | Words of Text PL/I | Number of Segments ALM | Number of Segments PL/I |
|---|---|---|---|---|---|
| Interrupt/Fault Dispatching | 70.2 | 1381 | 585 | 7 | 1 |
| Utility | 41.4 | 5907 | 8362 | 15 | 23 |
| Obsolete | 35.5 | 2989 | 5411 | 9 | 7 |
| Process Management | 23.6 | 1842 | 5967 | 4 | 22 |
| Initialization/Configuration/Shutdown | 14. | 3406 | 20906 | 10 | 46 |
| File System/Virtual Memory | 7.4 | 4273 | 53454 | 19 | 74 |
| IO System | 6.9 | 1628 | 21974 | 8 | 25 |
| ARPA Network | .5 | 92 | 19051 | 1 | 33 |
| Other | 0. | 0 | 353 | 0 | 1 |
| Total | 13.6 | 21488 | 136093 | 73 | 232 |
| Total (minus obsolete) | 12.4 | 18529 | 130652 | 64 | 225 |
| Total (minus obsolete and pℓ1_operators) | 10.1 | 14711 | 130652 | 63 | 225 |

Table V: List of ALM Procedure Segments by Category

| Category | Language | Words of text | Words of linkage | Number of entry points | Segment Name |
|---|---|---|---|---|---|
| 1-SI | alm | 116 | 56 | 0 | bootstrap2 |
| 1-SI | alm | 1712 | 8 | 0 | bootstrap1 |
| 1-SI | alm | 242 | 8 | 6 | slt_manager |
| 1-SI | alm | 262 | 8 | 1 | pre_link_2 |
| 1-SI | alm | 272 | 8 | 1 | pre_link_1 |
| 1-SI | alm | 30 | 22 | 1 | build_template_pds |
| 1-SI | alm | 38 | 10 | 1 | shutdown_switch |
| 1-SI | alm | 382 | 36 | 4 | tape_reader |
| 1-SI | alm | 64 | 14 | 3 | privileged_mode_init |
| 1-SI,RC | alm | 288 | 76 | 5 | init_processor |
| 2-ID | alm | 220 | 32 | 4 | signaller |
| 2-ID | alm | 240 | 90 | 21 | wired_fim |
| 2-ID | alm | 272 | 18 | 1 | fault_error |
| 2-ID | alm | 28 | 8 | 3 | parity_check |
| 2-ID | alm | 297 | 102 | 15 | ii |
| 2-ID | alm | 320 | 74 | 9 | fim |
| 2-ID | alm | 4 | 8 | 2 | return_to_ring_0_ |
| 3-FS,SC,S | alm | 58 | 8 | 2 | hash_index |
| 3-L | alm | 172 | 14 | 2 | get_defptr |
| 3-L | alm | 62 | 8 | 1 | datmk_util_ |
| 3-L | alm | 96 | 8 | 3 | lot_maintainer |
| 3-S | alm | 154 | 20 | 6 | salv_free_store |
| 3-SC | alm | 46 | 10 | 2 | kst_man |
| 3-SC,SSM | alm | 80 | 12 | 5 | get_ptrs_ |
| 3-SSM | alm | 104 | 60 | 26 | page |
| 3-SSM | alm | 1300 | 142 | 21 | page_fault |
| 3-SSM | alm | 136 | 72 | 6 | device_control |
| 3-SSM | alm | 142 | 36 | 7 | free_store |
| 3-SSM | alm | 218 | 52 | 5 | bulk_store_control |
| 3-SSM | alm | 220 | 36 | 14 | pc_trace |
| 3-SSM | alm | 220 | 56 | 20 | master_pxss_page |
| 3-SSM | alm | 234 | 42 | 2 | pre_page |
| 3-SSM | alm | 336 | 36 | 15 | pd_util |
| 3-SSM | alm | 52 | 16 | 7 | meter_disk |
| 3-SSM | alm | 563 | 12 | 19 | page_error |
| 3-SSM | alm | 80 | 24 | 5 | page_util |
| 4-PC | alm | 34 | 16 | 2 | level |
| 4-PC | alm | 6 | 8 | 1 | gate_init |
| 4-T | alm | 28 | 18 | 3 | vclock |
| 4-TC | alm | 1774 | 196 | 39 | pxss |
| 5-I | alm | 12 | 12 | 1 | ioam_check |
| 5-I | alm | 38 | 8 | 1 | call_detacher |
| 5-IOC | alm | 22 | 8 | 4 | dn355_util |
| 5-IOC | alm | 511 | 24 | 9 | iom_manager |
| 5-IOC | alm | 8 | 10 | 1 | dstint |
| 5-P | alm | 430 | 8 | 1 | prt_300_conv |
| 5-P | alm | 587 | 10 | 1 | prt_ccnv |
| 5-TP | alm | 20 | 8 | 1 | tape_checksum_ |

Table V - page 2

| Category | Language | Words of text | Words of linkage | Number of entry points | Segment Name |
|---|---|---|---|---|---|
| 6-E | alm | 106 | 56 | 3 | emergency_shutdown |
| 6-E | alm | 18 | 10 | 1 | check_trailer |
| 6-E | alm | 24 | 16 | 1 | syserr |
| 6-UI | alm | 138 | 34 | 3 | wire_stack |
| 6-UI | alm | 22 | 8 | 1 | fm_checksum_ |
| 6-UI | alm | 26 | 16 | 3 | get_proc_id |
| 6-UI | alm | 501 | 74 | 18 | privileged_mode_ut |
| 6-UI | alm | 61 | 16 | 1 | absadr |
| 6-US | alm | 10 | 12 | 1 | clock_ |
| 6-US | alm | 14 | 8 | 2 | unwinder_util_ |
| 6-US | alm | 18 | 8 | 3 | all_rings_util_ |
| 6-US | alm | 206 | 8 | 6 | condition_ |
| 6-US | alm | 28 | 10 | 2 | wired_utility_ |
| 6-US | alm | 3818 | 42 | 5 | pl1_operators_ |
| 6-US | alm | 917 | 8 | 2 | formline_ |
| 7-N | alm | 92 | 8 | 1 | imp_status_driver |
| 8-0 | alm | 113 | 8 | 1 | old_freen_ |
| 8-0 | alm | 12 | 16 | 4 | fast_hc_ipc_tv |
| 8-0 | alm | 143 | 10 | 1 | old_alloc_ |
| 8-0 | alm | 2574 | 14 | 13 | pl1_operators |
| 8-0 | alm | 30 | 8 | 1 | move_ |
| 8-0 | alm | 50 | 54 | 23 | sss_active_tv_ |
| 8-0 | alm | 53 | 8 | 2 | old_area_ |
| 8-0 | alm | 6 | 10 | 1 | tty_read_tv |
| 8-0 | alm | 8 | 12 | 2 | tty_write_tv |
| 8-0 | pl1 | 220 | 32 | 2 | accept_alm_obj |

Note: see Table VI for an explanation of category abbreviations.

## Table VI: List of Ring 0 Segments by Category (System 20.10a)

The following category abbreviations are used:

1. Initialization/Reconfiguration/Shutdown
   RC - Reconfiguration
   SI - Shutdown
2. IH - Interrupt/Fault Dispatching
3. File System/Virtual Memory
   FS - File System
   L - Linker/Search Rules/Working Directory
   S - Salvager
   SC - Segment Control
   SSM - Physical Storage Management
4. Process Management
   PC - Process Creation/Status/Destruction
   IPC - Inter-Process Communication
   T - Timers/ips masking
   TC - Traffic Control
5. IO System
   I - IOAM
   IOC - IOM/355
   P - Printer Control
   TP - Tape Control
   TT - Typewriter Control
6. Utility
   E - Error Handling and Tracing
   UI - Utility (Internal)
   US - Utility (Shared with other rings)
7. N - ARPA Network
8. O - Obsolete

Multiple tags indicate segments which fall in multiple categories. e.g. a tag of FS,S indicates a segment used both by the File System and the Salvager.

Table VI - page 2

| Category | Language | Text Size (words) | Linkage Size (words) | Number of entries | Segment Name |
|---|---|---|---|---|---|
| 1-RC | pl1 | 266 | 32 | 2 | dsu270_reconfig |
| 1-RC | v2pl1 | 2032 | 86 | 1 | reconfig |
| 1-RC | v2pl1 | 291 | 34 | 2 | add_memory |
| 1-RC | v2pl1 | 618 | 38 | 2 | delete_pd_records |
| 1-SI | alm | 116 | 56 | 0 | bootstrap2 |
| 1-SI | alm | 1712 | 8 | 0 | bootstrap1 |
| 1-SI | alm | 242 | 8 | 5 | slt_manager |
| 1-SI | alm | 262 | 8 | 1 | pre_link_2 |
| 1-SI | alm | 272 | 8 | 1 | pre_link_1 |
| 1-SI | alm | 30 | 22 | 1 | build_template_pds |
| 1-SI | alm | 38 | 10 | 1 | shutdown_switch |
| 1-SI | alm | 382 | 36 | 4 | tape_reader |
| 1-SI | alm | 64 | 14 | 3 | privileged_mode_init |
| 1-SI | pl1 | 1199 | 48 | 1 | initialize_dims |
| 1-SI | pl1 | 189 | 38 | 1 | syserr_init |
| 1-SI | pl1 | 192 | 44 | 4 | delete_segs |
| 1-SI | pl1 | 354 | 62 | 2 | shutdown |
| 1-SI | pl1 | 397 | 36 | 1 | load_system |
| 1-SI | pl1 | 469 | 112 | 1 | tc_init |
| 1-SI | pl1 | 470 | 42 | 1 | segment_loader |
| 1-SI | pl1 | 53 | 26 | 1 | clock_init |
| 1-SI | pl1 | 68 | 26 | 1 | build_template_dsegs |
| 1-SI | pl1 | 73 | 36 | 1 | initializer |
| 1-SI | pl1 | 744 | 68 | 2 | update_sst_pl1 |
| 1-SI | pl1 | 883 | 206 | 4 | initialize_faults |
| 1-SI | pl1 | 92 | 22 | 1 | find_peripheral |
| 1-SI | pl1 | 98 | 34 | 1 | tc_shutdown |
| 1-SI | v2pl1 | 1057 | 72 | 1 | scs_init |
| 1-SI | v2pl1 | 137 | 32 | 1 | init_hardcore_gates |
| 1-SI | v2pl1 | 1526 | 34 | 1 | tty_init |
| 1-SI | v2pl1 | 163 | 38 | 1 | init_sys_var |
| 1-SI | v2pl1 | 164 | 26 | 1 | initialize_gim |
| 1-SI | v2pl1 | 1701 | 76 | 2 | init_branches |
| 1-SI | v2pl1 | 187 | 66 | 2 | init_collections |
| 1-SI | v2pl1 | 223 | 36 | 1 | init_root_dir |
| 1-SI | v2pl1 | 252 | 26 | 1 | dn355_init |
| 1-SI | v2pl1 | 27 | 18 | 1 | io_init |
| 1-SI | v2pl1 | 300 | 44 | 2 | wired_shutdown |
| 1-SI | v2pl1 | 325 | 22 | 2 | make_sdw |
| 1-SI | v2pl1 | 364 | 38 | 2 | trace_init |
| 1-SI | v2pl1 | 382 | 36 | 11 | tape_io |
| 1-SI | v2pl1 | 436 | 102 | 1 | tape_init |
| 1-SI | v2pl1 | 49 | 14 | 1 | init_str_seg |
| 1-SI | v2pl1 | 527 | 24 | 1 | iom_data_init |
| 1-SI | v2pl1 | 658 | 28 | 2 | make_branches |
| 1-SI | v2pl1 | 71 | 12 | 1 | bulk_store_init |
| 1-SI | v2pl1 | 751 | 30 | 1 | init_sst |
| 1-SI | v2pl1 | 757 | 40 | 1 | scas_init |
| 1-SI | v2pl1 | 89 | 20 | 1 | printer_init |
| 1-SI | v2pl1 | 956 | 40 | 4 | dsu190_init |
| 1-SI,RC | alm | 288 | 76 | 5 | init_processor |
| 1-SI,RC | pl1 | 456 | 82 | 3 | stop_cpu |
| 1-SI,RC | pl1 | 54 | 22 | 1 | find |
| 1-SI,RC | v2pl1 | 120 | 26 | 1 | prds_init |

Table VI - page 3

| Category | Language | Text Size (words) | Linkage Size (words) | Number of entries | Segment Name |
|---|---|---|---|---|---|
| 1-SI,RC | v2pl1 | 153 | 22 | 2 | freecore |
| 1-SI,RC | v2pl1 | 533 | 84 | 2 | start_cpu |
| 2-ID | alm | 220 | 32 | 4 | signaller |
| 2-ID | alm | 240 | 90 | 21 | wired_fim |
| 2-ID | alm | 272 | 18 | 1 | fault_error |
| 2-ID | alm | 28 | 8 | 3 | parity_check |
| 2-ID | alm | 297 | 102 | 15 | ii |
| 2-ID | alm | 320 | 74 | 9 | fim |
| 2-ID | alm | 4 | 8 | 2 | return_to_ring_0_ |
| 2-ID | v2pl1 | 585 | 34 | 4 | parity_fault |
| 3-FS | pl1 | 1056 | 56 | 5 | acl_ |
| 3-FS | pl1 | 163 | 28 | 1 | check_gate_acl_ |
| 3-FS | pl1 | 1764 | 150 | 5 | append |
| 3-FS | pl1 | 222 | 38 | 3 | ring0_init |
| 3-FS | pl1 | 265 | 30 | 2 | acc_list_ |
| 3-FS | pl1 | 275 | 22 | 1 | match_star_ |
| 3-FS | pl1 | 282 | 52 | 1 | force_access |
| 3-FS | pl1 | 337 | 40 | 4 | quotaw |
| 3-FS | pl1 | 35 | 26 | 2 | quota_util |
| 3-FS | pl1 | 355 | 40 | 5 | fs_alloc |
| 3-FS | pl1 | 549 | 72 | 5 | ringbr_ |
| 3-FS | pl1 | 650 | 78 | 2 | del_dir_tree |
| 3-FS | pl1 | 862 | 128 | 7 | find_ |
| 3-FS | v2pl1 | 1056 | 56 | 3 | star_ |
| 3-FS | v2pl1 | 1160 | 94 | 3 | delentry |
| 3-FS | v2pl1 | 1232 | 78 | 16 | set |
| 3-FS | v2pl1 | 1484 | 80 | 11 | quota |
| 3-FS | v2pl1 | 1662 | 70 | 13 | status_ |
| 3-FS | v2pl1 | 212 | 20 | 2 | make_seg |
| 3-FS | v2pl1 | 2437 | 104 | 17 | asd_ |
| 3-FS | v2pl1 | 437 | 34 | 8 | level_0_ |
| 3-FS | v2pl1 | 491 | 34 | 3 | fs_move |
| 3-FS | v2pl1 | 559 | 64 | 3 | chname |
| 3-FS | v2pl1 | 566 | 62 | 3 | truncate |
| 3-FS,S | pl1 | 1087 | 52 | 5 | acc_name_ |
| 3-FS,SC | pl1 | 197 | 30 | 1 | move_file_map |
| 3-FS,SC | pl1 | 304 | 56 | 4 | dir_control_error |
| 3-FS,SC | pl1 | 337 | 52 | 2 | access_mode |
| 3-FS,SC | pl1 | 485 | 78 | 5 | sum |
| 3-FS,SC,S | alm | 58 | 8 | 2 | hash_index |
| 3-FS,SC,S | pl1 | 572 | 56 | 4 | hash |
| 3-L | alm | 172 | 14 | 2 | get_defptr |
| 3-L | alm | 62 | 8 | 1 | datmk_util_ |
| 3-L | alm | 96 | 8 | 3 | lot_maintainer |
| 3-L | pl1 | 134 | 24 | 1 | get_defname |
| 3-L | v2pl1 | 1036 | 68 | 4 | link_snap |
| 3-L | v2pl1 | 125 | 20 | 2 | unsnap_service |
| 3-L | v2pl1 | 234 | 28 | 1 | rest_of_datmk_ |
| 3-L | v2pl1 | 313 | 30 | 1 | get_defname_ |
| 3-L | v2pl1 | 632 | 36 | 1 | initiate_search_rules |
| 3-L | v2pl1 | 770 | 54 | 7 | fs_search |
| 3-L | v2pl1 | 998 | 66 | 7 | link_man |
| 3-S | alm | 154 | 20 | 6 | salv_free_store |
| 3-S | pl1 | 1087 | 40 | 2 | salv_check_thread |
| 3-S | pl1 | 1087 | 80 | 2 | salv_check_map |
| 3-S | pl1 | 1207 | 82 | 1 | salv_rebuild_directory |
| 3-S | pl1 | 1408 | 60 | 1 | salvage_entry |
| 3-S | pl1 | 194 | 32 | 1 | salv_clean_ast |
| 3-S | pl1 | 1979 | 100 | 3 | salvage_directory |

Table VI - page 4

| Category | Language | Text Size (words) | Linkage Size (words) | Number of entries | Segment Name |
|---|---|---|---|---|---|
| 3-S | pl1 | 247 | 48 | 3 | salv_truncate |
| 3-S | pl1 | 369 | 58 | 6 | salv_name |
| 3-S | pl1 | 372 | 54 | 1 | salv_delete_dir |
| 3-S | pl1 | 421 | 48 | 3 | salv_print |
| 3-S | pl1 | 516 | 54 | 5 | salv_check_ptr |
| 3-S | pl1 | 597 | 38 | 1 | salv_rebuild_names |
| 3-S | pl1 | 761 | 48 | 4 | salv_rebuild_acl |
| 3-S | v2pl1 | 1441 | 88 | 2 | on_line_salvager |
| 3-SC | alm | 46 | 10 | 2 | kst_man |
| 3-SC | pl1 | 115 | 32 | 1 | kst_entry_check |
| 3-SC | pl1 | 373 | 30 | 1 | activate |
| 3-SC | pl1 | 436 | 46 | 2 | setfaults |
| 3-SC | pl1 | 440 | 34 | 2 | kstsrch |
| 3-SC | pl1 | 549 | 40 | 2 | updateb |
| 3-SC | v2pl1 | 1044 | 76 | 6 | makeunknown |
| 3-SC | v2pl1 | 586 | 64 | 2 | boundfault |
| 3-SC | v2pl1 | 652 | 60 | 3 | deactivate |
| 3-SC | v2pl1 | 687 | 62 | 1 | seg_fault |
| 3-SC | v2pl1 | 689 | 56 | 4 | initiate |
| 3-SC | v2pl1 | 720 | 54 | 1 | get_aste |
| 3-SC | v2pl1 | 732 | 40 | 2 | makeknown |
| 3-SC,L | v2pl1 | 1296 | 66 | 14 | fs_get |
| 3-SC,SSM | alm | 80 | 12 | 5 | get_ptrs_ |
| 3-SSM | alm | 104 | 60 | 26 | page |
| 3-SSM | alm | 1300 | 142 | 21 | page_fault |
| 3-SSM | alm | 136 | 72 | 5 | device_control |
| 3-SSM | alm | 142 | 36 | 7 | free_store |
| 3-SSM | alm | 218 | 52 | 5 | bulk_store_control |
| 3-SSM | alm | 220 | 36 | 14 | pc_trace |
| 3-SSM | alm | 220 | 56 | 20 | master_pxss_page |
| 3-SSM | alm | 234 | 42 | 2 | pre_page |
| 3-SSM | alm | 336 | 36 | 15 | pd_util |
| 3-SSM | alm | 52 | 16 | 7 | meter_disk |
| 3-SSM | alm | 563 | 12 | 19 | page_error |
| 3-SSM | alm | 80 | 24 | 5 | page_util |
| 3-SSM | pl1 | 123 | 32 | 1 | assign_device |
| 3-SSM | pl1 | 290 | 60 | 3 | get_disk_meters |
| 3-SSM | pl1 | 388 | 58 | 1 | move_device |
| 3-SSM | pl1 | 420 | 58 | 7 | pc_wired |
| 3-SSM | pl1 | 497 | 52 | 4 | wire_proc |
| 3-SSM | pl1 | 742 | 78 | 15 | pc_trace_pl1 |
| 3-SSM | v2pl1 | 1548 | 50 | 4 | pc_abs |
| 3-SSM | v2pl1 | 1847 | 52 | 16 | dsu190_control |
| 3-SSM | v2pl1 | 2259 | 82 | 11 | pc |
| 4-IPC | pl1 | 368 | 60 | 5 | fast_hc_ipc |
| 4-IPC | v2pl1 | 468 | 54 | 6 | hc_ipc |
| 4-PC | alm | 34 | 16 | 2 | level |
| 4-PC | alm | 6 | 8 | 1 | gate_init |
| 4-PC | pl1 | 132 | 42 | 3 | plm |
| 4-PC | pl1 | 161 | 48 | 2 | init_proc |
| 4-PC | pl1 | 24 | 24 | 1 | stop_process |
| 4-PC | pl1 | 241 | 48 | 1 | activate_segs |
| 4-PC | pl1 | 261 | 58 | 3 | deact_proc |
| 4-PC | pl1 | 283 | 48 | 1 | deactivate_segs |
| 4-PC | pl1 | 371 | 80 | 1 | terminate_proc |
| 4-PC | pl1 | 485 | 38 | 1 | makestack |
| 4-PC | pl1 | 70 | 40 | 3 | proc_info |
| 4-PC | pl1 | 90 | 26 | 2 | access_viol |
| 4-PC | v2pl1 | 1250 | 88 | 3 | act_proc |

Table VI - page 5

| Category | Language | Text Size (words) | Linkage Size (words) | Number of entries | Segment Name |
|---|---|---|---|---|---|
| 4-PC | v2pl1 | 134 | 26 | 1 | proc_int_handler |
| 4-PC | v2pl1 | 175 | 26 | 1 | outward_call_handler |
| 4-PC | v2pl1 | 175 | 38 | 3 | ring_alarm |
| 4-PC | v2pl1 | 21 | 12 | 1 | get_page_trace |
| 4-PC | v2pl1 | 667 | 48 | 1 | initialize_kst |
| 4-PC | v2pl1 | 75 | 20 | 1 | get_process_usage |
| 4-T | alm | 28 | 18 | 3 | vclock |
| 4-T | v2pl1 | 258 | 30 | 3 | set_alarm_timer |
| 4-T | v2pl1 | 89 | 20 | 6 | ips_ |
| 4-TC | alm | 1774 | 196 | 39 | pxss |
| 4-TC | pl1 | 169 | 30 | 1 | wired_plm |
| 5-I | alm | 12 | 12 | 1 | ioam_check |
| 5-I | alm | 38 | 8 | 1 | call_detacher |
| 5-I | pl1 | 161 | 34 | 3 | ioam_ut1 |
| 5-I | pl1 | 198 | 56 | 7 | dstm_ |
| 5-I | pl1 | 698 | 52 | 6 | ioam_ut |
| 5-I | v2pl1 | 1856 | 76 | 13 | ioam_ |
| 5-IOC | alm | 22 | 8 | 4 | dn355_util |
| 5-IOC | alm | 511 | 24 | 9 | iom_manager |
| 5-IOC | alm | 8 | 10 | 1 | dstint |
| 5-IOC | v2pl1 | 144 | 18 | 1 | gim4 |
| 5-IOC | v2pl1 | 1616 | 56 | 9 | dn355 |
| 5-IOC | v2pl1 | 173 | 18 | 1 | gioc_stat |
| 5-IOC | v2pl1 | 210 | 30 | 2 | gim_alloc |
| 5-IOC | v2pl1 | 32 | 14 | 1 | channel |
| 5-IOC | v2pl1 | 388 | 32 | 1 | gim3 |
| 5-IOC | v2pl1 | 393 | 32 | 1 | gim1 |
| 5-IOC | v2pl1 | 64 | 18 | 1 | check |
| 5-IOC | v2pl1 | 878 | 72 | 6 | gim_assign |
| 5-IOC | v2pl1 | 94 | 18 | 1 | gim2 |
| 5-P | alm | 430 | 8 | 1 | prt_300_conv |
| 5-P | alm | 587 | 10 | 1 | prt_conv |
| 5-P | v2pl1 | 242 | 20 | 1 | printer_status |
| 5-P | v2pl1 | 988 | 86 | 6 | printer_dcm |
| 5-TP | alm | 20 | 8 | 1 | tape_checksum_ |
| 5-TP | v2pl1 | 1792 | 84 | 11 | tdcm |
| 5-TP | v2pl1 | 489 | 36 | 2 | tdcm_status |
| 5-TT | pl1 | 118 | 28 | 1 | tty_unlock |
| 5-TT | pl1 | 4153 | 286 | 7 | tty_inter |
| 5-TT | pl1 | 479 | 20 | 1 | tty_con |
| 5-TT | pl1 | 676 | 48 | 5 | tty_free |
| 5-TT | v2pl1 | 1883 | 30 | 1 | tty_read |
| 5-TT | v2pl1 | 2103 | 30 | 2 | tty_write |
| 5-TT | v2pl1 | 2146 | 60 | 8 | tty_index |
| 6-E | alm | 106 | 56 | 3 | emergency_shutdown |
| 6-E | alm | 18 | 10 | 1 | check_trailer |
| 6-E | alm | 24 | 16 | 1 | syserr |
| 6-E | pl1 | 108 | 28 | 2 | debug_check |
| 6-E | pl1 | 21 | 24 | 1 | call_bos |
| 6-E | pl1 | 254 | 36 | 3 | ring_0_peek |
| 6-E | v2pl1 | 1030 | 52 | 3 | copy_fdump |
| 6-E | v2pl1 | 19 | 16 | 1 | ring_zero_cleanup |
| 6-E | v2pl1 | 253 | 22 | 1 | verify_lock |
| 6-E | v2pl1 | 660 | 124 | 3 | trace |
| 6-E | v2pl1 | 938 | 74 | 9 | syserr_real |
| 6-UI | alm | 138 | 34 | 3 | wire_stack |
| 6-UI | alm | 22 | 8 | 1 | fm_checksum_ |
| 6-UI | alm | 25 | 16 | 3 | get_proc_id |
| 6-UI | alm | 501 | 74 | 18 | privileged_mode_ut |

Table VI - page 6

| Category | Language | Text Size (words) | Linkage Size (words) | Number of entries | Segment Name |
|---|---|---|---|---|---|
| 6-UI | alm | 61 | 16 | 1 | absadr |
| 6-UI | pl1 | 183 | 32 | 4 | thread |
| 6-UI | v2pl1 | 992 | 32 | 11 | lock |
| 6-US | alm | 10 | 12 | 1 | clock_ |
| 6-US | alm | 14 | 8 | 2 | unwinder_util_ |
| 6-US | alm | 18 | 8 | 3 | all_rings_util_ |
| 6-US | alm | 206 | 8 | 5 | condition_ |
| 6-US | alm | 28 | 10 | 2 | wired_utility_ |
| 6-US | alm | 3818 | 42 | 5 | pl1_operators_ |
| 6-US | alm | 917 | 8 | 2 | formline_ |
| 6-US | pl1 | 121 | 28 | 3 | cv_bin_ |
| 6-US | pl1 | 199 | 32 | 3 | unique_chars_ |
| 6-US | pl1 | 243 | 32 | 4 | cv_dec_ |
| 6-US | pl1 | 49 | 26 | 2 | unique_bits_ |
| 6-US | pl1 | 585 | 50 | 4 | date_time_ |
| 6-US | pl1 | 938 | 40 | 4 | object_info_ |
| 6-US | v2pl1 | 136 | 18 | 1 | area_assign_ |
| 6-US | v2pl1 | 202 | 12 | 1 | freen_ |
| 6-US | v2pl1 | 355 | 20 | 2 | alloc_ |
| 6-US | v2pl1 | 365 | 16 | 2 | area_ |
| 6-US | v2pl1 | 627 | 18 | 4 | signal_ |
| 6-US | v2pl1 | 84 | 20 | 2 | try_to_unlock_lock |
| 7-N | alm | 92 | 8 | 1 | imp_status_driver |
| 7-N | pl1 | 101 | 34 | 2 | imp_get_buffer |
| 7-N | pl1 | 103 | 24 | 1 | imp_global_status |
| 7-N | pl1 | 118 | 32 | 1 | iom_imp_dcm_read |
| 7-N | pl1 | 1238 | 132 | 14 | iom_imp_dcm_init |
| 7-N | pl1 | 1288 | 144 | 20 | ncp_main_ |
| 7-N | pl1 | 146 | 24 | 2 | imp_thread |
| 7-N | pl1 | 1769 | 178 | 5 | ncp_ |
| 7-N | pl1 | 182 | 44 | 5 | imp_wakeup |
| 7-N | pl1 | 193 | 30 | 1 | iom_imp_dcm_write |
| 7-N | pl1 | 194 | 38 | 3 | imp_util_wired |
| 7-N | pl1 | 194 | 44 | 5 | imp_util |
| 7-N | pl1 | 202 | 30 | 1 | imp_write_service |
| 7-N | pl1 | 211 | 56 | 5 | imp_service |
| 7-N | pl1 | 222 | 40 | 3 | ncp_ring_ |
| 7-N | pl1 | 2429 | 244 | 9 | iom_imp_status |
| 7-N | pl1 | 255 | 60 | 3 | imp_misc |
| 7-N | pl1 | 2713 | 412 | 4 | ncp_toop_ |
| 7-N | pl1 | 274 | 38 | 3 | imp_get_wired_buffer |
| 7-N | pl1 | 277 | 36 | 1 | imp_global_queue |
| 7-N | pl1 | 299 | 42 | 4 | imp_mark_host |
| 7-N | pl1 | 309 | 50 | 1 | imp_read |
| 7-N | pl1 | 317 | 58 | 5 | imp_lock |
| 7-N | pl1 | 32 | 26 | 1 | imp_cleanup |
| 7-N | pl1 | 406 | 56 | 2 | imp_write |
| 7-N | pl1 | 531 | 52 | 1 | imp_input_processor |
| 7-N | pl1 | 549 | 98 | 9 | imp_init |
| 7-N | pl1 | 612 | 132 | 21 | imp_error |
| 7-N | pl1 | 657 | 56 | 4 | imp_order |
| 7-N | pl1 | 726 | 78 | 4 | ncp_util_ |
| 7-N | pl1 | 741 | 158 | 4 | ncp_status_ |
| 7-N | pl1 | 779 | 72 | 5 | imp_input_processor_int |
| 7-N | pl1 | 887 | 88 | 7 | imp_attach |
| 7-N | pl1 | 97 | 30 | 1 | imp_release_wired_buffer |

Table VI - page 7

| Category | Language | Text Size (words) | Linkage Size (words) | Number of entries | Segment Name |
|---|---|---|---|---|---|
| 8-0 | alm | 115 | 8 | 1 | old_freen_ |
| 8-0 | alm | 12 | 10 | 4 | fast_hc_ipc_tv |
| 8-0 | alm | 145 | 10 | 1 | old_alloc_ |
| 8-0 | alm | 2574 | 14 | 15 | pl1_operators |
| 8-0 | alm | 50 | 8 | 1 | move_ |
| 8-0 | alm | 50 | 54 | 25 | sss_active_tv_ |
| 8-0 | alm | 55 | 8 | 2 | old_area_ |
| 8-0 | alm | 0 | 10 | 1 | tty_read_tv |
| 8-0 | alm | 8 | 12 | 2 | tty_write_tv |
| 8-0 | pl1 | 102 | 42 | 0 | usercode |
| 8-0 | pl1 | 1187 | 46 | 1 | dc_pack |
| 8-0 | pl1 | 220 | 52 | 2 | accept_alm_obj |
| 8-0 | pl1 | 255 | 42 | 1 | list_dir |
| 8-0 | pl1 | 285 | 40 | 1 | status |
| 8-0 | v2pl1 | 122 | 14 | 1 | get_entry_name |
| 8-0 | v2pl1 | 1538 | 74 | 5 | ex_acl |
| 8-0 | v2pl1 | 1704 | 80 | 0 | acl |
| Other | v2pl1 | 355 | 24 | 1 | date_name_ |