# CS452 Train Project

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## 1 About this report

The final report includes more insight into why we have implemented features in the way we have, as well as why we didn't implement certain features. We felt that we didn't discuss these topics enough in earlier reports, so we are including the discussion now.

## 2 Running the program

```
load -b 0x00218000 -h 10.15.167.5 "ARM/csulshoe/project.elf"
go
```

If you're feeling fancy and want to run the latest kernel that we ran:

```
l  ARM/csulshoe/m;g
```

The ELF file for this version is stored at `/u/cs452/tftp/ARM/csulshoe/project.elf` in the CS Student Computing Environment. The source code can be found at https://git.uwaterloo.ca/csulshoe/cs452/tree/master.

### 2.a Commands

| Command | Description |
|---|---|
| `tr <train_number> <train_speed>` | Set a train's speed. |
| `rv <train_number>` | Reverse a train. |
| `sw <turnout_number> <turnout_direction>` | Switch a turnout. |
| `sd <train_number> <train_speed>` | Run automated stopping distance calibration. |
| `v <train_number>` | Run automated velocity calibration. |
| `loop <train_number> <train_speed>` | Enter a loop around the track. |
| `r <train_number> <sensor> <offset>` | Stop at a location. |
| `t2start <train_number>` | Start random repeated routing. |
| `t2start <train_number>` | Stop random repeated routing. |
| `group <name> <train_number> [train_numbers]` | Link together a group of trains. Single train commands for grouped trains are not supported. |
| `ungroup <name>` | Go back to individual train control. |
| `trg <name> <speed>` | Set a group's speed. |
| `rvg <name>` | Reverse a group. |
| `set` | Set parameter. Useful parameters: `trains`: active trains. `track`: 0 for track A, 1 for track B. `spacing`: space between each pair of trains in a group. See `/usr/train/parameters.c` for more. |
| `go` | Start the train controller. |
| `stop` | Stop the train controller. |
| `q` | Quit. |

# 3 Vision

For our final project, we wanted to implement a system for creating, dissolving, and moving groups of trains as single units[1]. We also wanted to integrate reservations and routing with reversal into this system. Our goal was to have two or more groups of trains simultaneously routing to random locations on the track.

# 4 Features and implementation

Two trains with a 10-centimeter spacing can run as a group for over 10 minutes. Three trains with a 20-centimeter spacing can run for several minutes. Groups of trains can also be reversed. It is also possible for a single train to route to random destinations on sidings while a group of trains runs in a loop.

### 4.a Routing one train in the presence of a group

We allow one independent-minded, free-wheeling, anarchist train to route in parallel to a group. This train will constantly check whether it will run into the group (by projecting ahead its movements, and the movements of the other trains), and pick the highest speed that guarantees a certain distance from the other trains, for the foreseeable future (i.e. 500 ticks into the future or 140 centimeters, whichever comes first).

[1] Similar to how trucks platoon (they are even called "road trains"). https://youtu.be/lx9EFJ6qgZc

If lucky, you can encounter the independent train sneaking ("interleaving") inbetween the trains in a group, if the spacing in the group is big.

### 4.b Handling broken turnouts

To handle broken turnouts, we treat both branches of the turnout as if they connect to the same node in the track graph. This solution was easy to implement and allows trains to One downside is that we must recompile the project to change the list of broken switches. If we had more time, we would consider implementing automatic detection of broken turnouts.

### 4.c Sunsetting tasks

We came across a couple of situation where we wanted to kill a task and its children. Rather than changing our `Kill` syscall, we decided to create a message type `MESSAGE_SUNSET`. When a message of this type is sent to a task that is prepared to receive it, the task is expected to kill or sunset its children, then exit.

One disadvantage of this approach is that only servers can be sunset, whereas changing the `Kill` syscall would apply this behaviour to all tasks. Luckily, we only needed to apply this behaviour to the train conductor and multi-train conductor tasks, which are both servers.

## 5 Task structure

Note that the graph above is a DAG except for `Send()`s between the command dispatcher and the train conductors. These `Send()`s happen in a controlled fashion; in particular, the command dispatcher only ever sends to a train conductor if it is ready for a new train command and is thus send-blocked. In this way, we hope to make deadlock less likely.

### 5.a Train coordinate courier

We previously implemented the train conductor as a courier that regularly queried various servers to decide how to drive the train. As a result of this design, we wrote a lot of duplicated code and found it difficult to add new features to the conductor.

We decided for our final project to break the train conductor into two tasks: a server (the conductor) and a courier. The conductor calculates locations at which it needs to change the train's speed, reverse it, or flip a switch, then tells the courier to wake it up once the train has reached that location. The courier regularly polls the train coordinates server and sends a message to the conductor when the train has reached one of the specified locations. We found that the separation of location-tracking logic and train command generation into two tasks made it easier to implement new train behaviour.

### 5.b Multi-train conductor

To drive a group of trains as a single unit, we decided to implement a multi-train conductor and a corresponding multi-train coordinates courier. We thought this would be easier to implement than

The multi-train conductor is responsible for driving an entire group of trains. It is created when a `group` command is issued. It then creates a multi-train courier. This courier, in addition to waking the conductor when the first train in the group has reached given points on the track,

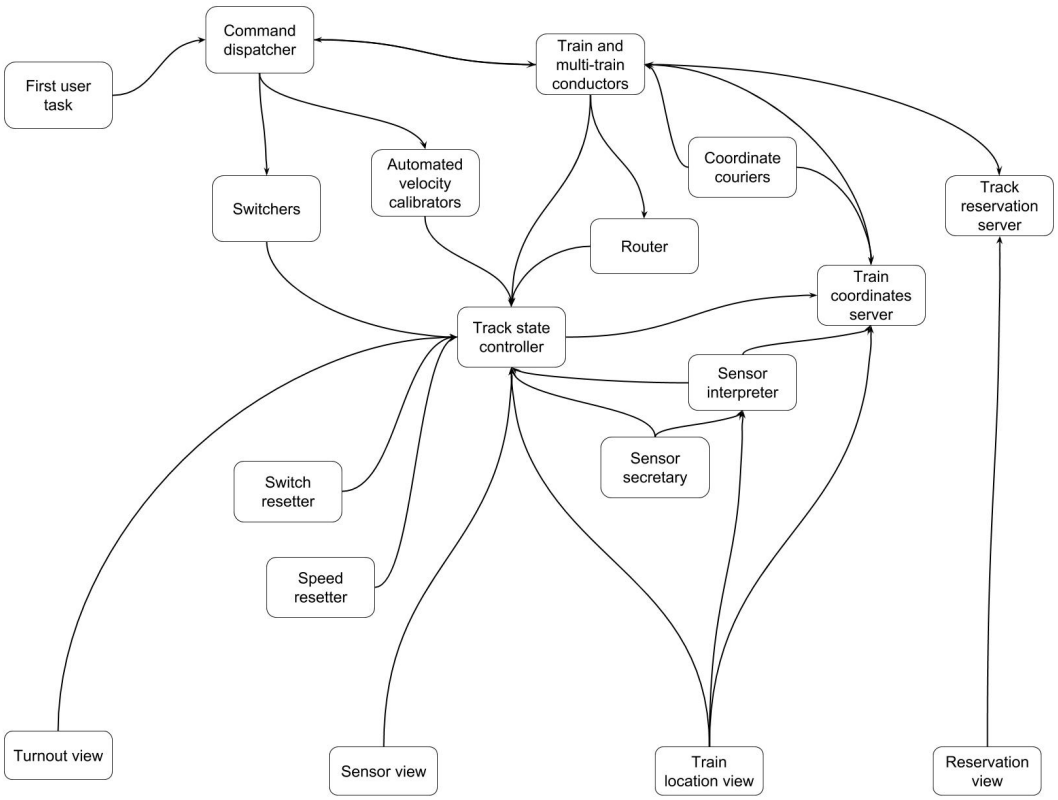


Figure 1: Diagram of our final project task structure, with arrows indicating `Send` calls between tasks. The clock and UART servers are not included in this diagram because many tasks send to them and they do not send to any task. Notifiers are not included because each only sends to its corresponding server.

sends a message when the spacing between two consecutive trains in the group is out of a tolerated range. In this way, the multi-train conductor makes sure that all the trains in a group stay at a given distance from each other.

#### 5.b.1 Speed modulation: an alternative solution

We also considered creating a task that would rapidly change a train's speed between two integer speeds, with the goal of moving the train at an average velocity between the velocities of the two speeds. We decided to implement spacing control as described above because we believed it would be simpler. However, in hindsight, we think that the modulator approach might have resulted in less variation in spacing. We could have programmed the modulator to choose an average speed that would keep it near the optimal spacing, rather than only correcting the spacing once it is outside the acceptable spacing range.

## 6 Unimplemented optimizations

We could not convince ourselves that optimizing our performance is necessary. Although our idle time with `-O2` enabled is 60% on average, this did not seem to degrade our project's performance. If it had been necessary, we did have several ideas for optimizations to make:

- Change the CPU speed[2]
- Optimize our `memcpy` implementation
- Use smaller messages in most cases (since every message sent is over 200 bytes)
- Run selected `-O3` flags (since building with `-O3` breaks the kernel)
- Use a linked list instead of a min-heap for the clock server queue
- Reduce kernel data structure size
- Fix `-O3`
- Apply link-time optimization
- Use vectored interrupts

## 7 File and repository hashes

The last commit on the branch `master` has SHA `450c2213be2d5b85efb9c54c02bccd6752bc3fa2`.

### 7.a MD5 hashes

```
a5ab21bd63e960032282b0c6006de5cc  .gitignore
4bbdec35a4b9dc9ca8615b1e321de502  .gitmodules
58bb9fbcf62dc59a35491ac53f0b612a  .travis.yml
cdbd7fbeb502f2adcba5aeb12b7e8e8c  Doxyfile
a04b33b9acdae3fd32fb9fc7a6f2676a  Makefile
72528caa4dc861d6f0f2590e0aac6000  PULL_REQUEST_TEMPLATE.md
ad052ff44c768126f46bf67c4e7dd7b1  README.md
fffb471c0ef031de7290e9803a651aac  gcc-ld
```

[2] https://wiki.embeddedarm.com/wiki/TS-7200#Setting_the_CPU_Clock_Speed

```
d7810fab7487fb0aad327b76f1be7cd7  gcc-ldCOPYING
10b31708f10ca2e4a77d04495578cb8b  include/bwio.c
1506ac36c03fc3c02a62124aec4dbf20  include/bwio.h
1e06c47ed88775686330932eb570b056  include/io.h
28fb38ae413a58784deb9e362e2e56d0  include/myio.c
457e6a7c749f4040044aa4be852fd290  include/myio.h
0ff6bee28590e1b949a208361291deab  include/mytimer.c
8958f41681273f9891540bc5289bb6e4  include/mytimer.h
9e66057d63ac6141d27d3f7d627298b8  include/rawio.c
2314714decf98c1fde63b96f2ffaf2ab  include/rawio.h
a51b441bd12f84e40333d2dfde291780  include/timer_data.h
74c63a11fc85af6c146dbcb5fa19b14a  k2benchmark.txt
51f1ce428a9a07d7b7b394f9c8302279  kernel/asm/kernToUser.s
d1d5fe7833e97870de0e1539f8581727  kernel/asm/startup.s
dc310ba0937f8818a8735c4fed086051  kernel/asm/trap.s
770dc066a65a334181fb303745f14dad  kernel/include/labenv/timer.c
a5d669bd2921cb530cd57401cf86af26  kernel/include/labenv/timer.h
38cfc8c969ea2246fc27635304fd1947  kernel/include/labenv/ts7200.h
ee90c5ee9fadbe5f7cf574db5241d256  kernel/include/versatilepb/timer.c
4cd17ccd0c85a77c30bb7df4ead73ae7  kernel/include/versatilepb/timer.h
3eee261c61989efe86d9a2f1ebe11638  kernel/include/versatilepb/versatilepb.h
99df351d9e5ab9ece03655fe6145919c  kernel/src/cp_vec.c
503fb56ff1929bcc8d7a6b3d19b2524e  kernel/src/cp_vec.h
31f8a414fa662b4739b2d868a6fffda9  kernel/src/events.c
ba6a3c142b44633cc80c765f36939f62  kernel/src/events.h
c0a56fc847482c7b0792c2d01439dbd9  kernel/src/handle_abort.c
b84f77628074c219bdf86a19907f4fed  kernel/src/iio.c
580fbeb1bc250578424ff209253649fa  kernel/src/iio.h
07b8601fe7f1dbfb85e55a311a0bf890  kernel/src/interrupt.c
f105abe4e0d376eb9a0e700e20a9e626  kernel/src/interrupt.h
76700aef2b03a9c6e439328e3829139b  kernel/src/kassert.c
8baadeeeeb32c820cce4b6420efcb92b  kernel/src/kassert.h
c7f303448c61cd0b620060ef10915cb8  kernel/src/kusage_stats.c
c1ed6afa70cb921f87c0e90770edb87b  kernel/src/kusage_stats.h
56ff6f6f508b29ede42e0cf2831ca2c7  kernel/src/multitasking/messaging.c
8da39e0fbf99d840a126cad76ea4ed57  kernel/src/multitasking/messaging.h
d8f5950a0cac94759ad5200fb735ddd1  kernel/src/multitasking/ready_queue.c
acdaabac90092feb2d815d93daa6c160  kernel/src/multitasking/ready_queue.h
149c5145f09e141dd7a5c68ba1bd3c2f  kernel/src/multitasking/schedule.c
a11a9befd765f6c6c048f6b84860d0f9  kernel/src/multitasking/schedule.h
5864d87dbe1c10fd564ccd73a3b06a6d  kernel/src/multitasking/scheduler.c
2a6005ff964276bd1f83ba93f2e06b86  kernel/src/multitasking/scheduler.h
1ff609f65cd9531a647ce6575c039b6f  kernel/src/multitasking/send_queue.c
d2fd55f45ab57e8e5c75a5a072bb74ec  kernel/src/multitasking/send_queue.h
920cbd04b31f243120179cc369514d87  kernel/src/multitasking/task.c
b20b570ef1305a2e44efb45b8919064f  kernel/src/multitasking/task.h
4ad860fd0d43e6a9cf29eacf89e2b06d  kernel/src/queue.h
6d76892b73c6e93ed9d1b8cd1f9db93e  kernel/src/syscall/syscall.c
0d26653864f2251c8a286335fc5d4c2a  kernel/src/syscall/syscall.h
64661f8128c9d1edfd59240e625a414c  kernel/src/vic.c
61bf440b522595f947ffc92a4aa30bcb  kernel/src/vic.h
910ddd9774bc89c04f804f76669354ce  lib/a0codes.h
bec5edf5b40af4209c289f8c83f248ef  lib/attributes.h
59506a2fc8c1e78f1287e2d9eb454b34  lib/benchmark.c
3b7d15e91a197c4a1a4cdfbe674f88b1  lib/benchmark.h
ec862c22bb31b480dce098dda7c8899f  lib/buffer.h
7949f4bf8c52321c0bcf49e3b67817ff  lib/buffertypes/char_buffer.c
4ca46294d99b93f653cbe9c850362146  lib/buffertypes/char_buffer.h
```

```
0dd2910bf5314d67758f17c17ef855ee  lib/buffertypes/int32_t_buffer.c
5f0d55eeb4a647b2929700f046d402d7  lib/buffertypes/int32_t_buffer.h
c88d49ec2cb3eddadb74da74fdad0f0e  lib/codes.c
dbcecff713b5e55b43f3a44db4d006a7  lib/codes.h
d41d8cd98f00b204e9800998ecf8427e  lib/constants.c
06e84818bb23369072347e52dc27ab46  lib/constants.h
38424f2856725ba4ce4919eefe5e3142  lib/crash.h
608c3732de6719e206bf1c76772bd549  lib/crash.s
dd7ed407227be8ff5e72530a2e86ada4  lib/event_data.h
cde83ace20f384ad7cb8992aca78205b  lib/groups.c
f80558f230c378c5c64e44a7443034e4  lib/groups.h
c11cd47bb8d467b89ff85ea6cb1e6784  lib/messages.h
f16c0325983ba4883ecf69748fb865e3  lib/priority_queue.h
468099d70d970b441648ba67e04a095a  lib/terminal.h
af9cdf9014bec08c6df74cead3ca105d  lib/track/README.txt
24bb477557f6df611901467842ff7286  lib/track/model.c
f52586fee7643827909bc1cf5a284296  lib/track/model.h
cdc0890b052aefe296680600c99cb346  lib/track/model_data.h
7707b57cb3a6c3703c0e3da3acbef763  lib/track/parse_track.py
1e06c8505279ed9f4d10136465c81618  lib/track/parts_tracka
a408ef1736b356024bf0dc2bc05d98b0  lib/track/parts_trackb
824a2ba5c1322789a24bc93d5fc02bc5  lib/track/track_data.c
b8eb24d93f121785802d88c0df0ff722  lib/track/track_data.h
98329bc12eab0da15637137782f9cab8  lib/track/track_node.h
50e0b1150b39a2425cb2180c33e0e57f  lib/track/tracka
dab2764f1d7f07aa454bad2ec01158b8  lib/track/trackb
90572a2b6c9203c958dac2978dd2b3e5  lib/track/tracks.c
84244d5defb8528197eff11a8a3b21ee  lib/track/tracks.h
4d096f022c5038dedd3a77053a58b86d  lib/tstdlib.c
8e768a4e0cc06e3f9a8e88277777e06d  lib/tstdlib.h
e80f2789ca24d327bac466b79ccc5290  lib/tstring.c
2a7117fdcadd90f1e3029ad923292f15  lib/tstring.h
06e369b76c2d125b61ac6a95d7d31309  lib/usage_stats.c
2c7495e2cf58fe43659b7ac7fed0b7ee  lib/usage_stats.h
e4eb310dce47b65766735c6be662ca28  lib/user_command.c
95390bfc04d43f5b9bc472c393eb789b  lib/user_command.h
e377e05740f18eef528361f788f1c7f8  main.c
04a99fa4e57230b2b2b7a525a1105097  main.ld
d9cd792c1413ac79bf45f799ae903f42  reports/a0-csulshoe.pdf
2d81bda8e6453ea87e964edefb8d37c5  reports/k1.pdf
3c476edf2886bdb295d9f5e37a748d9c  reports/k2.pdf
e962ebaab43701b2baa697adfbe05f7d  reports/k3.pdf
4569f774527daad1d1c706f112f26701  reports/k4.pdf
018c24286bccf2165d3a6824aed3fb47  reports/project.pdf
caec5627ce3fd40404d86e59d23f9578  reports/t1.pdf
dd92518ba98d61faa06b6abfbd61b584  reports/t2.pdf
8eac36235a94a3ff97768fe881ca16ef  scripts/parse_calib_log.py
7c70fec0ceecb03f5246ce63d01cbf9e  scripts/train_data_analysis.ipynb
1c7a429e1ced54dbb23098d3078a30e8  stats.md
da4d2d5a9d3d7971c83928f051ef6b58  test-resources/assert.c
c1e9354e62486019325b3d7e096f17b4  test-resources/assert.h
b1a7d80ccd36efa7b4db75a7a6a9195a  test/Makefile
d41d8cd98f00b204e9800998ecf8427e  test/e2e/__init__.py
5e5251a0b50afa28bf4b46424a6b3d26  test/e2e/qemu_tcp_wrapper.py
f1e50c9027d900c43570595e642fd518  test/e2e/snapshots/k2.txt
57e0cf79450fa3e8dc465928d0e82668  test/e2e/snapshots/k3.txt
2135a39d326e969a7a1aff8ed796464c  test/e2e/snapshots/printf_happy_path.txt
5c894b95e44a5b8d0e850fc07fa45f93  test/e2e/test_clock.py
```

```
ae866e7f08a01d7a30c0af14d98b426c  test/e2e/test_commandparsing.py
1b2357ce0443c4771348ecf34ffefb29  test/e2e/test_destroy.py
8f749bae092472967cd325ee379e4d03  test/e2e/test_getcputc.py
bf210ede7d676c369e780b20587c3f5b  test/e2e/test_interrupts.py
939ce9936dc62dba256a3a3b18f4ecd2  test/e2e/test_kernel_demo.py
207f9c96a203fb1408236396eb8c4da1  test/e2e/test_messaging.py
7c5b77b452f247c0ae43ca889d8f6e7f  test/e2e/test_model.py
63428d6fbf558a456bfd1503dbffb217  test/e2e/test_mypriority.py
b137b49b04d3fd3a55f7aa94d500f799  test/e2e/test_nameserver.py
ae138404be6f232656b675c3293e73ee  test/e2e/test_new_conductor.py
ea6c74f451c3f6249b431406c5fcb2e2  test/e2e/test_prediction.py
705f20c8af9c2bb6be26efcab7a8caac  test/e2e/test_printf.py
e8fcdd41235268e20a8b4ce8ff2ac0a9  test/e2e/test_router.py
f7c6f842ecb68d41b2167ad29552b783  test/e2e/test_segfaults.py
40ac38c0dddc0f7411311cf6edf7e455  test/e2e/test_servers.py
7fb29482e6a120a9c872c287021092b3  test/e2e/test_sleeper.py
30e544606327baabd6afe99c229faf9f  test/e2e/test_test.py
3834f5e022525034f78b19b6d5b764fa  test/unit/test_all.cc
65a92d844a6d98056dffd9024003fbfc  test/unit/test_all.h
916f5fab4c3bf56c62b8588863c9cd76  test/unit/test_buffer.cc
097d11f425ed7b415cba26be7efbc158  test/unit/test_buffer.h
5fb6e05d355b3e0750cfc5c0207eb80f  test/unit/test_clock_wait_queue.cc
825a054548d34057930fc5cbea517933  test/unit/test_clock_wait_queue.h
be7726ba1a922ec5ab26525114d7704d  test/unit/test_messaging.cc
f34aa46731d487e48a5cd1a9a681b518  test/unit/test_messaging.h
1909548396588628d189701a805e7bb4  test/unit/test_ready_queue.cc
917d4146f8727af1b9986cd4b94565a3  test/unit/test_ready_queue.h
ee004b6ffd40e6513204bdd28474af7f  test/unit/test_scheduler.cc
c31f7630705c36d377356eace6e86c9b  test/unit/test_scheduler.h
ebf57a23d6c248f7de1547e67b2900c7  test/unit/test_stdlib.cc
664c5ed933718c9c833e37a4663e6ef4  test/unit/test_stdlib.h
feb2d463f057a6d3b342f467e7682ce2  test/unit/test_task.cc
36889e34775aefba76462f7ede00349b  test/unit/test_task.h
c9b58c9e1c8ad02c462127291bfb09cf  test/unit/test_track.cc
aee0704af0e8051ce4e99397ea677080  test/unit/test_track.h
bc8c5d7bfc797a46f4599eca7f2743cb  test/unit/test_track_data.cc
b4300d87e1872fa230f6ff9e73a4de23  test/unit/test_track_data.h
dc0401121ffb9ab3e52aadf942489a00  usr/anti_freezer.c
10bc02d24438f9ca4f6490c7676a6aac  usr/anti_freezer.h
c9bfaaf830a8165687dace03e554a6c5  usr/clock.c
b4566bc63807ef8e5e47e70ae6140774  usr/clock.h
929fb54a2371e5a0a5c96316bd993360  usr/command_dispatcher.c
9aaa1aa63b4a96a912de3557edfa4f03  usr/command_dispatcher.h
c1a84bc2d0e1e77eda929b31f622dfb5  usr/idle.c
0850a1ff169d4bf316f23f252bd1a1a2  usr/idle.h
e8ca8a6998df91215838705f41662823  usr/ioserver.c
b36ecddf097fc6d11a72b09a64bcae6a  usr/ioserver.h
686bfad6b5f7a70f10865e0bc29a5249  usr/k1.c
758b67d7c795e165ba195c0d39d6bbe0  usr/k1.h
b8923150be8054c9bfa75bd511f9bc21  usr/k2.c
c383d0978426f930db936eb03b5090ef  usr/k2.h
3efb1e872f6ea02246e5d87f3fccce8c  usr/k3.c
87e3b6299a0d9261e6a0a3dc7a0adaa2  usr/k3.h
3f9b92e877e51c8a6556121920a974e6  usr/lib/clock_wait_queue.c
836be31c955cd68fb41d2fc263cadab7  usr/lib/clock_wait_queue.h
e2d4643a2b52bbcf79f4a4a94b86a598  usr/lib/global_track_state.c
cde4e70f68f7f9a395d220f9fb9dc307  usr/lib/global_track_state.h
0186cd2be5fe906309783bcef070b5c8  usr/lib/search_node_queue.c
```

```
605036af1536d568a4dc2f9727bdb31e  usr/lib/search_node_queue.h
f23ab005de96d571487ac46cd51672cd  usr/nameserver.c
b943c7708fafeb759a3ddc25706848e8  usr/nameserver.h
d76670df6cf30ef0ed1fe8a365082522  usr/notifier.c
a266f655714bf034e10ee80066a04045  usr/notifier.h
af2abe9121bca71e89c28585dc45f71b  usr/project.c
1197326e3537355a3fb7fd3316565fe7  usr/project.h
7ccda1fde79e5fff5c57f7cb05260fd6  usr/sleeper.c
b5d4716690d6fe5cfef9eb7114da798d  usr/sleeper.h
7c3d3b1b7553e85b5ac5c952b19eb0f2  usr/spam.c
c6b26aad9c868a310e2a61543f1b6d54  usr/spam.h
c76fea6b27a5e29f1f61097ac827164b  usr/test/awaitevent/test_rx_terminal.c
987024da0946d3bc51fa9b517aba1e4d  usr/test/awaitevent/test_rx_terminal.h
324862e41991fa243099d43763f7d490  usr/test/awaitevent/test_timer_interrupt.c
fd0230e03c6329d23cd59ce714d14841  usr/test/awaitevent/test_timer_interrupt.h
7609b1ef434e30e5c7d49477fb636423  usr/test/awaitevent/test_tx_terminal.c
c4db6de70684fda79da761d55c674458  usr/test/awaitevent/test_tx_terminal.h
31041ff5a0154e679718472f2cd150eb  usr/test/clock/clock_util.c
74a779c5688003aa346dc6d18d84a2d4  usr/test/clock/test_clock.h
4df05ca408a98b04ecb8e5a4647342ec  usr/test/clock/test_clock_accuracy.c
7b58840919f048032eab36dcaec632bf  usr/test/clock/test_clock_errors.c
7e5373809fd8b91e2c3aa4dee4872665  usr/test/clock/test_clock_syscall_accuracy.c
bed867b2ad5bb4aae38a223eb2a750ba  usr/test/clock/test_clock_syscall_errors.c
1aec1fc4678cc0f19d9ab8b7de0387ce  usr/test/conductor/test_conductor.c
1b1c55d0f2b485ffbe6711783881d94d  usr/test/conductor/test_conductor.h
4954616cc85aeb0b6840385438ae814a  usr/test/conductor/test_coordinate_courier.c
ab2aa40748abdb4ad91b0958ef41a707  usr/test/conductor/test_coordinate_courier.h
ca831d5b374cae3c232f46f5a620e730  usr/test/destroy/test_destroy.h
7145bd0c23a6ccc35d7b9bee765fda4e  usr/test/destroy/test_destroy_block_kill.c
c57a920919fb3190f13de17219e6aca8  usr/test/destroy/test_destroy_many_tasks.c
0493f74de96ce23b3cfd6a978ed14722  usr/test/destroy/test_destroy_nameserver.c
0a92605d5d76da9cd664f3106f9a6058  usr/test/destroy/test_destroy_parent_tid.c
ae156df9cd60b84db962141ae273c743  usr/test/destroy/test_destroy_send_queue.c
4cfba04d3a6dc896ae6c9f6730ba34cd  usr/test/destroy/test_destroy_task_limit.c
1377b67b1599f9e97f783013fecc80cc  usr/test/iio/test_getcputc_errors.c
606ca77a18d32ae87856761098065e97  usr/test/iio/test_getcputc_errors.h
96b46eae0fce398869696ba43e175bf2  usr/test/iio/test_getcputc_happypath.c
943f5683a7afd3a053e5a864aa586a35  usr/test/iio/test_getcputc_happypath.h
091124f3277913c6339829b031478ea7  usr/test/iio/test_printf.c
93d9372b059af217848ce09cf45e69c4  usr/test/iio/test_printf.h
661a668400e184f442e4a9110730ba29  usr/test/messaging/test_messaging.h
d262f35cce581eda07aff2484fd2d8b5  usr/test/messaging/test_messaging_basic.c
4e0595b514cecd036282b86b0d1ddc02  usr/test/messaging/test_messaging_exit_with_blocked.c
497af6748eae1fdaf6a437d80dcce337  usr/test/messaging/test_messaging_fifo_send.c
f0abb91510a1c1433da5977ba2a1881d  usr/test/messaging/test_messaging_invalid_tid.c
6ac01327ddbffa06649f0c20ed04e8ec  usr/test/messaging/test_messaging_receive_before_send.c
76583e962409b9a90c62df1e97b74598  usr/test/messaging/test_messaging_reply_target_zombie.c
47c902d889407fee469b052bec91585c  usr/test/messaging/test_messaging_same_priority.c
a17bf4e6f1b05c814f24c35fe3cd5677  usr/test/messaging/test_messaging_send_recipient_zombie.c
c85eef4e381e81e765ec21f4154f21d3  usr/test/messaging/test_messaging_sequence.c
7b973bb3f9a91d9cd292229d0c90f11d  usr/test/messaging/test_messaging_tree.c
8bd72ff578d51d007fe156e698e1b48c  usr/test/messaging/test_messaging_truncation.c
b7f826a49bea1adb7411f4a567a32da5  usr/test/model/test_constant_velocity_model.c
2d5f41fe282686888719ea2a31cfa214  usr/test/model/test_distance_between_track_nodes.c
a77c6a1463c080c16ccc9012cd2130e9  usr/test/model/test_model.h
7dc17c7a46e288536c3ea61c03fb0be0  usr/test/model/test_sensors_are_paired.c
dde567ac51c2941dbc500461d145829a  usr/test/model/test_stopping_distance_model.c
02235009ba1e99236fe1fbc988037ee9  usr/test/model/test_stopping_time_model.c
```

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7101f020db73ffcf486747bebce6150b  usr/test/nameserver/ns_tid.c
7e087751d128cd0916702f843843f3d0  usr/test/nameserver/ns_tid.h
2d3f90279df9fe86d7b8241d0e2f7a15  usr/test/nameserver/test_nameserver_happypath.c
9ae182d2a7d7d6a327d70d6593eea0de  usr/test/nameserver/test_nameserver_happypath.h
fbb92e62ce4cdab26d53efd17ac977c5  usr/test/nameserver/test_nameserver_too_many.c
90a28211c3a519e8eb53142e3443de96  usr/test/nameserver/test_nameserver_too_many.h
97e4576bd06081ac956acb15838a51f6  usr/test/nameserver/test_nameserver_wrapper_errors.c
0e290966f99895d1a336e40a7857b5bb  usr/test/nameserver/test_nameserver_wrapper_errors.h
e681205fdd5a9de2be0afd0de95ee8f5  usr/test/prediction/test_collision_prediction.c
1186f84ea7d0b75b886a7bc6a88d66f1  usr/test/prediction/test_collision_prediction.h
dcaf99b2b86d19addf3f7d824834e7b5  usr/test/prediction/test_next_switch_prediction.c
84bd775abde969811cc61563e6fda113  usr/test/prediction/test_next_switch_prediction.h
a986a875e17f12e97045d1ec9e265154  usr/test/prediction/test_stopping_location_prediction.c
063957dc7b7c23ce549ac1c2eae05055  usr/test/prediction/test_stopping_location_prediction.h
9f14c14716882e04d47d0b79acf46d1e  usr/test/router/test_router.c
e8d41ac2d589a5df498d8c07399f7b0d  usr/test/router/test_router.h
1e3029788d9d92f284f79fdaab0de8a5  usr/test/router/test_router_basic.c
b24f175ebe1b186681e8c2b6691e2c67  usr/test/router/test_router_complete.c
5e373b88083446a63e5ad365b2a5e38b  usr/test/router/test_router_same_sensor.c
eb5e08f03a76fbbde7feebd87649cfe9  usr/test/router/test_router_sensor_pair.c
55b673474c1e0944fba7c30726445528  usr/test/servers/test_track_reservation_server.c
e2df5bda86c4ca88b09e453e5b029e7c  usr/test/servers/test_track_reservation_server.h
87e69fef7d70e663454b43b9dc2a4150  usr/test/servers/test_train_coordinates_server.c
66d7c115ce8fe1f138a7da2a9798235f  usr/test/servers/test_train_coordinates_server.h
584b1793c6028a44a658c25521241aab  usr/test/sleeper/test_sleeper.c
7eb5b27ae1e889a4a81dd541bf62b9a0  usr/test/sleeper/test_sleeper.h
a8e19df150c1fa62d1f8b68cd13ea758  usr/test/test_message_benchmark.c
109f0d4968b39ef3cff5e0559a91eb71  usr/test/test_message_benchmark.h
83869951c54ac75ae2d68223a8cde7fd  usr/test/test_mypriority.c
40ff8628c0cf51b8fbc2bff1a2ad6113  usr/test/test_mypriority.h
fab5c0fa7a428dd197a0fa1cc516bf79  usr/test/test_runner.c
9a86e82edaa8d85403087223c06375d4  usr/test/test_runner.h
e22f4b33d4b2703e4fb73230ed9d8195  usr/test/test_undefined_handler.c
83053e202339e79cbc203b0570f028a5  usr/test/test_undefined_handler.h
68cb6a79094d8d27d2bcd50df9ed003b  usr/train/calibration/acceleration_calibrator.c
5f95de37ebf4f3e62c8dc3699261ff0d  usr/train/calibration/acceleration_calibrator.h
1d722b33a2664e55f31e72b04b780e51  usr/train/calibration/stopping_distance_calibrator.c
c6ffd8a34444416c0b5bbe0d625d330b  usr/train/calibration/stopping_distance_calibrator.h
1cded7ce548c611e9bc86595c53235c0  usr/train/calibration/velocity_calibrator.c
aff38ab9ff0cb570e25fb82b98e49373  usr/train/calibration/velocity_calibrator.h
ce4455dbfdae36ab97621813d508fbbf  usr/train/commands.c
f06db3f8d27d5f76447cc29b8d2a0720  usr/train/commands.h
eb7ae4f2312be651f114ac9e4b78fd61  usr/train/coordinate_courier.c
5c2386d79f082d340ef425d9af562e07  usr/train/coordinate_courier.h
a7576574c21945738aedfd8fbd2a95fe  usr/train/multi_coordinate_courier.c
dc5fa5e898db7ace436bd37b91a6bbb7  usr/train/multi_coordinate_courier.h
d8d366e4f5400cc8dc07d184251c001d  usr/train/multi_train_conductor.c
beeb221c2d683efdc78492108395fbd5  usr/train/multi_train_conductor.h
8fa2b15aa28e96a7476f0aa82fe3e39c  usr/train/parameters.c
6aaabba4d80d0565edc1b28d219d2496  usr/train/parameters.h
d6a0eb7a59ffc6397c9a121bab9bad18  usr/train/prediction.c
739715adc03d3581b726651c9c26a07c  usr/train/prediction.h
6af3eb53e40f69937af4200b01e61688  usr/train/reverser.c
d4a5df8b7e670131ff68b6b54ae7fb4f  usr/train/reverser.h
5f8a5280751070e85ee27107e8bf147b  usr/train/router.c
80f047badcd9e066045e821dae520f73  usr/train/router.h
cb62649a507b8a1d8f91877a83d06953  usr/train/sensors/sensor_interpreter.c
ffbddd984bda4ee04fcba3d508d6969c  usr/train/sensors/sensor_interpreter.h
```

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0a7a80f0e6d43929eff4461353f8ae85  usr/train/sensors/sensor_secretary.c
1a63accf05f4a4f7624a088732419811  usr/train/sensors/sensor_secretary.h
af126d28779b6f728fad4325409853a1  usr/train/speed_resetter.c
d4024b31f38c93aef87f0783abbe4c13  usr/train/speed_resetter.h
d51def28c55022766433b2e28911ba6d  usr/train/switcher.c
111a40ac8534996f38b1223a527558df  usr/train/switcher.h
52e8d4a3d6f45c363620fbb0daa27768  usr/train/t2_demo_task.c
117a61c39894ae28b0adfccb79cdeb13  usr/train/t2_demo_task.h
6494c2fcdc525d35e748c901c2bab734  usr/train/track_reservation_server.c
e93daae1d74fc9fa8deec80af5f43f46  usr/train/track_reservation_server.h
ad55da1ed0b95c9638d13186ec2afcb6  usr/train/track_state_controller.c
0e08b6ee35eb03666ce1bb5b8e343ae4  usr/train/track_state_controller.h
c9e4fbd752348fd6694e8130b7e6a1e5  usr/train/train_conductor.c
489079823eb4e3855d799edff68daa35  usr/train/train_conductor.h
d4323357441265204e8ce0700bbc9176  usr/train/train_coordinates_server.c
18bf12524a057d145842b8acdc259da7  usr/train/train_coordinates_server.h
51adcfe509f86ae6ef46b4b95356b489  usr/train/train_model_courier.c
d0441721ca0e417e1927c1824ccf9cbd  usr/train/train_model_courier.h
39cfd7f38b96bd0e809c55617924df7f  usr/train/train_util.c
21db9a9eb7b51c6e87b1ebc82cdca9da  usr/train/train_util.h
d5881d3437ddfce89545e333ca545c04  usr/train/turnout_resetter.c
b2edaf6afa9268eb4e8b30c435f06f9b  usr/train/turnout_resetter.h
6cae62c97dc3e1b1de204974a295e55a  usr/user_data_abort.h
45499fb865c9b64dfaf169deb0522088  usr/views/clock_view.c
3ffdc9be852e4ad6ef8064d500fbb8da  usr/views/clock_view.h
b246f0a914e16aead3a80bd7584ce56b  usr/views/reservation_view.c
61c8aaeb0e6b1490795eca0464c7f798  usr/views/reservation_view.h
68a12eeef2bc46b909d291586161f41b  usr/views/sensor_view.c
a17a17ab1f35fcad994faa3b8e416a37  usr/views/sensor_view.h
944854ca01c1e1eb0cde8a052fb97668  usr/views/train_location_view.c
d89d8cf1e29843162dfa843277b8db4a  usr/views/train_location_view.h
3ea97403bbeab21a28a11217d31c8754  usr/views/turnout_view.c
f14ac6112e4e42db3cd24a298a6d5cb4  usr/views/turnout_view.h
a7668b81a997cb9d602415320f5d33f3  versatilepb.ld
3f052cb7f6b25c5e80dca05f284701d3  versatilepb_e2e.ld
c06605bea54e7505a4ceadee05e53a6a  versatilepb_e2e_iio.ld
89441cccfbea450f485e451770d95f95  versatilepb_e2e_iiotmr.ld
03a9a6a402360d35fe9d1aedfd8e98e7  versatilepb_e2e_tmr.ld
```